STUDIES ON THE GROWTH ACTIVITIES OF SOME COMMERCIALLY IMPORTANT PLANTS

ABSTRACT

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

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IN

BOTANY

BY

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DEPARTMENT OF BOTANY
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ABSTRACT

The present study on the structure and behaviour of vascular cambium and its derivatives tissues - the food conducting (secondary phloem) and the water conducting (secondary xylem) pathways has been under taken in relation to different weather conditions of the study site and age of the selected trees *Ceiba pentandra* (L.) Gaertn., *Ficus glomerata* Roxb. *and Moringa oleifera* Lamk. for two consecutive years (2003 & 2004). The findings are summarized as follows:

The vascular cambium is semi-stratified in *C. pentandra*, typical non-stratified in *F. glomerata* and *M. oleifera*. It forms a continuous cylinder and is made up of fusiform and ray initials. The fusiform initials are found to vary in length from 212.50 -712.50 μm in *C. pentandra*, 150.-612.50 μm in *F. glomerata* and 125.00 - 437.50 μm in *M. oleifera*. The fusiform initials undergo considerable size variation with growing girth of the stem axis. The length of fusiform initials shows an increasing trend from top toward the base of the tree in *C. pentandra* and in *F. glomerata* initially it increases and exhibit declining trend at the base while in *M. oleifera* the length exhibit increasing tendency with the advancing age and soon gets stabilized near the base. This increase in length goes up

to 24% in *C. pentandra* 23% in *F. glomerata* and 46% in *M. oleifera* respectively.

The ray initials multiply to become more in number as the trunk grows older and wider. New rays arise either by cutting off tips or sides of fusiform initials or by transverse segmentation of the later.

The wood is diffuse porous in all the three species investigated. The pores are either solitary or in radial multiples of 2-12.

The average length of vessel elements shows an increase with the increasing girth of the axis in *C. pentandra*. In *F. glomerata* and *M. oleifera*, average length of vessel elements initially increases with the age and after experiencing a slight decline again there is a gain in length with the advancing age. The radial and tangential diameter of vessel elements in *C. pentandra* and *F. glomerata* first undergo expansion with increasing age of the axis which is followed by a declining tendency near the basal regions. In *M. oleifera* radial diameter shows an initial increase and appear to be followed by constancy while tangential diameter shows an increasing tendency from top towards the base. The length of vessel elements vary from 100.00-500.00 μm in *C. pentandra*, 62.50-

525.00 μm in *F. glomerata* and 125.00-400.00 μm in *M. oleifera* in different months of a calendar year with average length of vessel elements is measured 353.46 in *C. pentandra*, 264.00 μm in *F. glomerata* and 279.04 μm in *M. oleifera* under different seasonal influences.

The mean length of xylem fibres shows a positive increase with growing size of the trunk and the average length of fibres has been found to vary from 1134.00-1828.00 μm in *C. pentandra*, 1031.50-1416.00 μm in *F. glomerata* and 571.00-736.00 μm in *M. oleifera*.

The bark as usual is made up of three distinct zones viz, conducting phloem, non-conducting phloem and periderm. The sieve-tube members possess mostly oblique sieve plates on their end wall in *C. pentandra*, slightly oblique to transverse in *F. glomerata* and mostly transverse in *M. oleifera*. They vary in length from 162.50-450.00 μm in *C. pentandra*, 150.00-412.50 μm in *F. glomerata* and from 187.50-400.00 μm in *M. oleifera* and their average length is measured 324.42 μm, 266.08 μm and 269.29 μm respectively due to seasonal influence. They occupy about 28% transactional area in *C. pentandra*, 25% in *F. glomerata* and 27% in *M. oleifera*.

A gradual increase in the length of sieve-tube members along the tree axis of varying girth has been observed in *C. pentandra* and *M. oleifera*, while it declines near the base in case of *F. glomerata*.

The phloem fibres are distributed in the secondary phloem in a characteristics pattern in *C. pentandra*, *F. glomerata* and *M. oleifera*. They grow in length 2.427-4.298 times over the length of their mother initials in the different species investigated. They vary in length from 650.00-2500.00 μm in *C. pentandra*, from 625.00-2300.00 μm in *F. glomerata* and from 250.00-1300.00 μm in *M. oleifera* in different months of a calendar year.

The activity of vascular cambium initiates at different times in different species. Swelling of cambial cells occur in early May in *C. pentandra*, in mid-January in *F. glomerata* and in early June in *M. oleifera*. The cells begin to divide in mid May in *C. pentandra*, in late January in *F. glomerata* and in mid June in *M. oleifera*.

The cambium turns dormant in late November in *C. pentandra* and *M. oleifera* while in *F. glomerata* dormancy is attained in late September. The total amount of xylem produced in measures about 1950 μm in *C. pentandra*, 2150

μm in *F. glomerata* and 1600 μm in *M. oleifera*. In *C. pentandra* and *F. glomerata* the newly produced derivatives differentiate first into phloic elements, but in *M. oleifera*, the newly produced derivatives differentiate into phloic as well as xylem elements simultaneously.

The phloem production takes place in the months of May, June and July in *C. pentandra*, in January, February and July in *F. glomerata* and in June, July, August, September and November in *M. oleifera*. Precursor phloem is noticeable in *C. pentandra* in the month of January. The total amount of phloem produced during a calendar year is about 645 μm and 150 μm precursor phloem in *C. pentandra*. In *F. glomerata* and *M. oleifera*, the phloem production is about 260 μm and 430 μm respectively. The cambium remains active for about 7 months in *C. pentandra*, 9 months in *F. glomerata* and 6 months in *M. oleifera*.

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Dedicated

To my

Beloved Parents

Prof. M. Ishrat Husain Khan
(Dean & Chairman)
M.Sc. Ph.D. (AMU)

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Certificate

This is to certify that the thesis entitled ***"Studies on the growth activities of some commercially important plants"*** for the award of **Doctor of Philosophy** is a faithful record of bonafide research work carried out by ***Mohammad Azam Musharraf*** under my supervision. No part of this work has ever been submitted for the award of any other diploma or degree.

15-6-05

(Prof. M. Ishrat Husain Khan)
Supervisor

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15.06.05

(Mohammad Azam Musharraf)

CONTENTS

Introduction

INTRODUCTION

The chief characteristic feature of all the vascular plants, by which their name is derived, is the presence of specialized conducting system. These vascular plants include four phyla of the plant kingdom:

1. Psilopsida (chiefly fossils)
2. Lycopsida (club mosses)
3. Sphenopsida (horsetails)
4. Pteropsida (ferns, gymnosperms, angiosperms)

The vascular system is embedded in non vascular tissue commonly referred to as ground tissue. This tissue may be composed of different kinds of cells, each frequently forming a more or less solid complex, like, collenchyma or sclerenchyma in the outer cortex, parenchyma in the inner cortex, photosynthetic parenchyma in the leaf, and parenchyma, sclerenchyma, or both in the pith. The vascular tissue is commonly surrounded by parenchyma and is associated with sclerenchyma. A considerable proportion of sclerenchyma arises from the same meristem as the vascular tissues do and is therefore treated as part of the vascular system.

Vascular cryptogams and monocotyledons generally form their entire body by primary growth, whereas in gymnosperms and woody dicotyledons primary growth is followed by secondary growth that augments the vascular tissues through the activity of a localized meristem, the vascular cambium. Hence, in most dicotyledons and gymnosperms, stems continue growing in girth even after they have ceased to

elongate. The successive addition of secondary phloem and secondary xylem derived from the cambium provides new conduits for translocation and additional elements for mechanical support in branching and enlarging bodies of shrubs and trees (Iqbal, 1989).

Almost majority of the woody angiosperms and gymnosperms exhibited periodic growth in height as well as in thickness as long as they remain alive. It is, therefore trunks of the trees get thicker and thicker with the advancing age. Growth in linear direction is the result of the activity of the "apical meristem" while growth in diameter (secondary growth) is caused mainly by the meristematic activity of the "lateral meristem" i.e., the vascular cambium and phellogen or cork cambium. These two meristems produce secondary tissue, namely secondary xylem, secondary phloem and cork (phellem) and secondary cortex (phelloderm). In a three dimensional view, the cambium forms a continuous sheath about the xylem of stems, roots and their branches and also extends occasionally into the leaves (Khan, 1977). In a number of dicotyledons and gymnosperms, stems continue to grow in thickness even after they have ceased to elongate. The vascular cambium originates from the procambium, which in its course is derived from the actively dividing, and enlarging meristematic cells of apical meristems of shoots axis. During the progressive maturation of the derivatives of apical meristems, an undifferentiated part of the procambium is left in meristematic state. This undifferentiated part later develops into the vascular cambium also known as fascicular cambium, which occurs between the primary phloem and xylem of the primary vascular system. In most of the plants, the cambium is reported to undergo successive active and dormant phases

during a growth year, with certain exceptions among tropical species in which the cambial activity continues all the year round and in guava it shows intermittent growth activity (Khan, 1977). This specific behaviour of the cambium is believed to be controlled by several internal and external factors such as hereditary constitution, physiological phenomena and environmental conditions of the habitat.

The vascular cambium defined as a lateral meristem composed of fusiform and ray initials. Anatomical evidence for the presence of a vascular cambium occurs in representatives of all the major upper Paleozoic plant lineages, including the progymnosperms, lycophytes, preferns, ferns, sphenophytes, and gymnosperms. The existence of a vascular cambium is based on the presence of a tissue with a specific set of anatomical characters might lead one to conclude that the meristem in all the various lineages exhibited identical patterns of activity. This is apparently not the case, and there is substantial evidence of significant developmental variability in the vascular cambia of different plant groups. Fossil lycophytes, preferns, ferns, and possibly some sphenophytes were characterized by unifacial, determinate cambia; several sphenophytes may also have possessed a determinate cambium that was bifacial. In contrast, the bifacial, indeterminate pattern found in extant gymnosperms and dicots was apparently present not only in the progymnosperms and primitive seed plants. As to the more detailed aspects of cambial development, circumferential enlargement of the meristem in lycophytes and sphenophytes appears to have been accommodated principally through the process of fusiform-initial enlargement rather than by multiplicative division of fusiform initials. Some sphenophytes were also

characterized by a developmental pattern in which multiplicative division of ray initials and conversion of ray initials to fusiform initials were important in the circumferential expansion of the cambium. Finally, in the carboniferous seed fern *Medullosa*, there is an evidence of positional variability in initiation of the cambium. The initials appear to have formed around groups of adjacent sympodia in the eustele of the stem. With the subsequent production of secondary vascular tissues by this meristem, the distinct vascular segments characteristics of this stem type were delineated. The occurrence of significant development variability in the vascular cambium of early plants suggest that the meristem evolved independently in the different groups, an idea further supported by the fact that there is no resemblance of secondary growth in any trimerophyte or zosterophyllophyte, the fossil groups regarded as ancestral to the above lineages (Banks, 1968).

Concept of cambium:

The cambial zone normally consists of an unbroken cylinder of meristematic cells arranged in radial files that extend into mature secondary tissues where the radial arrangement may become obscured by changes during differentiation. Dividing cells on the outer side of the cambial zone form phloem mother cells, while those on the inner side form xylem mother cell. The transition in the cell type and activity through the cambial zone is gradual, particularly in the active cambium of dicotyledons.

There are two conceptually different views regarding the nature of cambium. One school of thought postulates a multiseriate zone in which all the cells are equally endowed

with multiplication capacity. This view, proposed by Raatz (1892) has been strongly supported by Catesson (1964). She defines the cambial zone as those cell layers which are characterized by the greatest RNA contents, are the site of most abundant mitosis and are distinguished in section by radially narrow cells with thin walls. The other school pleads for the uniseriate nature of cambium. There are two interpretation of this uniseriate concept based on terminological differences. According to one, there exists a single initials cell which, in each radial files of cambial cells lies somewhere between the phloem and xylem mother cells, and is responsible for the production of cambial derivatives on both outer and inner sides. This view mainly advocated by Bannan (1955, 1968) and Newman (1956), has been supported by ultra structural studies of Mahmood (1968) and Murmanis (1970) pertaining to tangential wall characteristics. According to another group of workers Wilson *et al.* (1966) Zimmermann and Brown (1971) the term cambium is applicable only to the initial cells, not the immediate derivatives. Thus, admittance of a single initiating layer is common in both the interpretations, the only difference being that one group of worker applies the term cambium to the entire meristematic zone consisting of the initiating layer as well as the tissue mother cells, i.e. the zone of periclinal division, while the other restricts it to the initiating layer only (Iqbal and Ghouse 1985a, 1987 and Iqbal 1989). Following the former terminology, Butterfield (1975) defines the cambium as a multiseriate zone of periclinally dividing cells lying between the differentiating secondary xylem and phloem, with distinct initials capable of both periclinal and anticlinal divisions lying somewhere within each

radial file of cells. The same terminology has been adopted for describing the cambium in the present study.

Sufficient work has been done on the structure and behaviour of the vascular cambium and production of vascular tissues in a number of temperate species, but limited information is available about Indian tropical plants. Further, most of the studies carried out in the past, lack proper statistical analysis. Much, therefore, remains to be known about the patterns of radial growth in Indian tropical trees and their cellular organization, with age and varying climatic conditions.

In fact, no information is available with regard to the cambial activity and formation of its derivatives in *Ceiba pentandra* (L.) Gaertn., *Ficus glomerata* Roxb. and *Moringa oleifera* Lamk. It is worth noting that all of them are of immense economic importance as they are highly important from medicinal point of view. It was considered to investigate the structure and behaviour of cambium of these species under varying conditions of age and season.

The proposed study shall attempt empirically to investigate the follows –

(i) Phenology of some selected species.

(ii) Formation of vascular cambium and its derivatives

(iii) Periodicity of cambium

(iv) Production of phloem and xylem

(v) Longevity of phloem

GENERAL INFORMATION REGARDING THE SPECIES SELECTED FOR PRESENT PROJECT OF RESEARCH -

1. *Ceiba pentandra* (L.) Gaertn.

Class	:	Dicotyledonae
Family	:	Bombacaceae
Genus	:	*Ceiba*
Species	:	*pentandra*
Common name	:	Safed simul
		(White Silk Cotton Tree)

Description:

An elegant tree 20 - 30 m. in height with a clear bole of 12 m. and thick buttresses. Branches horizontal, verticilate, armed with woody conical prickles when young; bark greyish brown; leaves digitately compound; leaflets 5-9, lanceolate cuspidate, elliptic, acute, entire or serrulate at apex, 7-10 cm. Long; petioles 7-25 cm; flower white, yellowish or rose-coloured in axillary fascicles; calyx 1.25-2 cm. High, glabrous without; pedicles 2.5-5 cm; petals oblong - obovate, 2.5-4 cm. long; staminal tube bearing apically 3-10 (mostly 5) filaments, anthers 1-3 called; ovary glabrous; style 2.5-3.5 cm; portion enclosed by staminal tube much thinner than exerted part; capsules oblong; seeds numerous, globose or obvoid, black, densely enclosed in long silky unicellular hairs, arising from the inner walls of the capsules.

Distribution:

A genus of deciduous, mostly spiny trees, distributed in tropical America, Asia and Africa one species *C. pentandra*, has been introduced into India which is found throughout the hotter parts of India, especially in Southern and Western India and the Andaman Islands.

Economic Importance:

Various parts of the tree are used in indigenous medicines. The roots are stimulant, toxic, diuretic, emetic and antispasmodic. They have hypoglycaemic effect and are useful in diabetes, dysentery and gonorrhoea. The young leaves are emollient; decoction of leaves is used to wash hair.

The flowers are demulcent, and useful in leucorrhoea. A decoction of flowers is taken as laxative. The bark is emetic, diuretic and astringent and febrifuge. The unripe pods are astringent and demulcent, useful in vertigo and migraine. In Nigeria, seed oil is used in rheumatism. The tree yields a dark almost opaque gum (Hindi-Hathia ka Gond) similar to tragacanth and is used as a substitute of Katira gum. It is astringent, toxic and laxative. The gum is given in bowel complaints, painful micturition and gonorrhoea.

It provides the floss known as KAPOK in trade. The main use of kapok is for insulating and stuffing purpose in life belts, life jackets and in surgical bandages etc.

2. *Ficus glomerata* Roxb.

Class	:	Dicotyledonae
Family	:	Moraceae
Genus	:	*Ficus*
Species	:	*glomerata*
Common name	:	Gular

Description:

A tree, up to 60 ft. high; bark smooth, reddish brown; young shoots glabrous pubescent or scaberulous. Leaves long, ovate-oblong or elliptic–lanceolate, glabrous, prominently nerved beneath; petiole 0.5–1.5 in, glabrous; stipules 0.5–1 in long; ovate-lanceolate, scarious, pubescent. Fruits red when ripe, 1-2 in diameter, sub-globose or pyriform, borne in large clusters of receptacles on short leaf- less branches emerging from the trunk and the main branches. The male, female and gall flower are all found together in the same receptacles. Male flowers: near the mouth of the receptacle & sessile. Sepals 3–4, membranous, inflated, enveloping the 2 anthers. Filaments connate. Gall flowers: Stalked. Perianth gamophyllous, irregularly toothed. Style lateral, elongate, stigma clavate. Fertile flower nearly sessile, forming a layer near the walls of the receptacle. Perianth gamophyllous, with 4 or 5 long lanceolate teeth, enveloping the small tuberculate achene. Style sub-terminal, stigma clavate. Fruits are sychonus and it generally ripe from March to July.

Distribution:

It is found through out the India from the outer Himalayan ranges to S. India and Ceylon. Its western limit beings Rajputana and the Salt Range of the Punjab.

Economic Importance:

The bark contains 14% tannin. It is astringent and decoction of it is used as a wash for wounds. The root is reported to be useful in dysentery. The leaves ground to powder and mixed with honey are given bilious affection. The fruits are astringent, stomachic and carminative. The milky juice is administered in piles and diarrhoea.

It may be used for outhouse doors, cross pieces for carts, rice mortars, planks and shutters and for making toys and effigies, cheap furniture, sides of carts, frames, ploughs, oars, yokes, bellows, and fuse box fitting. It may be used also in cheap turnery work, e.g., bed lags, lacquer ware and cotton reels, and as light packing case wood. It is reported to be suitable for match boxes.

3. *Moringa oleifera* Lamk.

Class	:	Dicotyledonae
Family	:	Moringaceae
Genus	:	*Moringa*
Species	:	*oleifera*
Common name	:	Sahjana, Sainjna
		(Horse Radish Tree)

Description:

A small or medium sized tree, about 20 feet high with corky bark, wood soft, young parts tomentose. Leaves 1-2 ft, usually tripinnate; petiole slender, sheathing at the base; leaflets elliptic. Flowers 1 inch in diameter, white, fragrant, in large penicles. Sepals linear- lanceolate, reflexed. Petals narrowly spathulate. Fertile filaments villous at the base. Ovary hairy capsule 9-20 in, pendulous, 9-ribbed. Seeds about 1 inch long, trigonous, winged at the angles. Flowers, February to April, and the fruit ripen in May and June.

Distribution:

A small genus of quick - growing trees distributed in India, Arabia, Asia Minor and Africa. Two species are recorded from India, of which one *M. oleifera* is widely cultivated in the sub-Himalayan tract, from chenab eastwards to Sharda, and cultivated all over the plains of India.

Economic Importance:

All parts of the tree are considered medicinal and used in the treatment of ascites, rheumatism, venomous bites and as cardiac and circulatory stimulants. The roots of young trees and also root bark are rubefacient and vasicant. The leaves are rich in vitamin A and C and are considered useful in scurvy and catarrhal affections; they are also used as an emetic. A paste of leaves is used as an external application for wounds. Flowers are used as tonic, diuretic and cholagogue. The seeds are considered antipyretic, acrid and bitter. The seed oil is applied in rheumatism and gout. The roots of the tree are used as condiment or garnish in the same way as those of tree horseradish.

Geographical Set-Up

GEOGRAPHICAL SET-UP

Aligarh is one of the most important districts of Uttar Pradesh located in the north-western part of the State at a distance of about 130 kms. from Delhi. The district of Aligarh spreads from 27°29' to 28°11' north latitudes and 77°29' to 78°38' east longitudes. It lies in the central part of the Ganga - Yamuna doab. It is bounded by Bulandshahar district in the north, Mathura district in the south and southwest and Etah district in the east and southeast. The extreme north-eastern boundary is formed by the river Yamuna which separates Aligarh from Gurgaon district of Haryana State.

Physical features:

The topographic features of the Aligarh district are similar to those found in the other parts of the Ganga-Yamuna Doab. Physio-geographically, the district contains vast alluvial plains, having gentle slope from north to south and southeast, and is drained by rivers Ganga in the northeast and Yamuna in the northwest.

From the low khaddar of the Ganga river in the east, the level of the district rises sharply to the high uplands which crowns the old flood bank of the river Ganga and then descends inland gradually to a depression, drained by Nim and Chhoiya Nadis. Beyond which, it rises again to the bank of Kali nadi. Along the right bank of the Kali nadi, is another sandy to silty belt rising from the low and narrow khaddar belt of the stream. Adjoining it is a fertile belt of loam soil, which sinks gradually into the broad depression.

Through the centre of the district, a broad belt of low-lying land runs from northwest to southeast. This broad low-lying belt is in fact the continuation of the belt which begins from the district of Meerut, passing through the Ghaziabad and Bulandshahar districts, enters Aligarh district from Koil tehsil in the north. The depression is narrow in the north and gets wider towards the south and it eventually passes into the adjoining district of Etah. It is believed to be a part of a very extensive low-lying tract which runs through the centre of the doab, parallel to the rivers Ganga and Yamuna. This tract is characterized by imperfect drainage and numerous jhils in which the surface water collects.

Beyond this depression, the surface rises again into a level plain known as western uplands. In the northwest, the general characteristics of the doab are maintained, loam alternating with clay in the depressions and with lighter ground on the banks of the few drainage channels, till finally comes the high cliff of the Yamuna. From here, the level drops to the khaddar of Yamuna. In the southwest of the district, sandy tracts with practically no depressions are found.

Topographically, the district represents a shallow trough (sauce-pan shape) like appearance. On the basis of topography the district could be divided into three divisions:

(1) The khaddar plains found mainly along the river Ganga in the east and along the river Yamuna in the west.

(2) The eastern and western uplands.

(3) The central low-lying tract.

Geologically, Aligarh district forms a part of the Indo-Gangetic plain which came into existence in the Pleistocene period. This

land lying in front of the newly up heaved mountains (Himalayas) formed a depression, which was rapidly filled up by the waste of the high lands.

Climate:

Aligarh district experiences tropical monsoon climate characterized by two extreme conditions of severe cold in winters (January maximum temperature 21°C and minimum 4°C) and oppressive heat in summers (June maximum temperature 43°C to 47°). The climate is in tune with that normally prevails in the western part of Uttar Pradesh. The rainfall is scanty ranging 60 to 75 centimetres per annum. The district is affected by the Northeast and Southwest monsoon in a year. Based on these two monsoon winds, the Indian meteorological department has divided the year into four seasons.

1. The cold weather season (Dec. - Feb.)
2. The Hot weather season (March - Mid June)
3. The season of general rains (Mid June - Mid Sept.)
4. The season of retreating monsoon (Mid Sept. - Nov.)

1. Cold Weather Season:

The cold weather season is characterized by cold and dry air which blows continuously during the three months of December, January and February. The sky is generally clear and cloud cover rarely exceeds two-tenth. During this season, the temperature falls and pressure rises as a result of which a high temperature belt develops over north India which influences this district.

The beginning of this season is marked by a considerable fall in temperature. The mean monthly temperature varies from 17.9°C to 18.8°C in November and it falls during December and varies from 13.0° to 14.3°C. The temperature experiences a further decrease in January when the average comes down to 10.7°C. As compared to January, temperature start rising from February and its mean vary 15.9°C to 17.3°C (Table-1). The direction of prevailing winds is normally from west and northwest to east and southeast. The winds are dry and light and generally blow at an average speed of about 3.2 kms. per hour.

The rainfall in winter months is very low and irregular. This rain is brought by the western depressions originating in the north of Atlantic and proceeding eastwards with the prevailing western lies. The average rainfall caused by these disturbances, is recorded 0.0 to 11.5 mm from December to February.

2. Hot Weather Season:

This season begins with a rise in temperature and decrease in pressure. In March, the temperature starts rising. The months of May and June record exceptionally high temperatures. The days are characterized by intensive heat, dry air and low relative humidity. A regular phenomenon of this seasons is the blowing of hot and dry winds locally called as 'loo,' which blow with great velocity (March 5.5 kms and in June 10.5 kms per hour). Another peculiar phenomenon of this season is the occurrence of dust and thunderstorm, which are locally known as 'andhi'. During the period of May and early June they are more frequent and sometimes move at a speed of 48 to 64 km per hour. These storms are short lived and

sometimes they cause rains with winds, thunder and blinding dust. However, it brings an appreciable decrease in the temperature. The air becomes cold and one gets temporary relief from the oppressive heat. No rainfall, except for a small amount accompanied by the thunderstorms, makes drought situation severe during this seasons.

3. The Season of General Rains:

By the middle of June, changes occur in the weather phenomenon. This is called, over north India, as the burst of monsoons. The atmospheric temperature falls with the arrival of the humid oceanic currents and the air becomes cool and pleasing by the end of June. The average relative humidity is 71.35% in July and 51.15% in October. Generally, the rains set in by the end of June or by the first week of July and continue till the end of September or by the first week of October. July and August are the rainiest months and having average rainfall 269.5 mm in 2003, but in 2004, August and September are the rainiest months and having average rainfall 162.5.

4. The Season of Retreating Monsoon:

The southwest monsoon ends by September or from the beginning of October. It is characterized by the hot and sticky weather and rise in temperature which starts falling by the end of October. The skies are clear and relative humidity falls to 50.0%. Sunshine due to clear sky causes a slight increase in the day temperature but the temperature in the night decreases slightly because of the dryness of air. However, by the end of October the humid oceanic currents are replaced by the dry continental air. This period may be considered as the period of transition between the hot wet weather and cool dry

Table-1: Mean monthly temperature, rainfall and humidity during 2003 & 2004.

Months	2003			2004		
	Temperature (°C)	Rainfall (mm)	Humidity (%)	Temperature (°C)	Rainfall (mm)	Humidity (%)
January	12.1	8.0	77.7	10.7	3.5	92.7
February	17.3	11.5	79.7	15.9	-	68.7
March	21.3	-	69.0	22.5	-	48.0
April	27.4	-	41.0	27.6	2.4	51.3
May	31.6	12.0	26.3	29.6	13.0	54.7
June	34.3	25.0	47.3	31.4	27.5	60.3
July	24.7	368.9	81.7	31.8	25.4	61.0
August	27.6	170.0	88.0	30.3	138.1	78.7
September	27.0	94.0	84.3	26.8	187.0	78.3
October	25.3	-	50.0	24.9	95.0	52.3
November	18.8	-	65.3	17.9	-	51.0
December	13.0	-	75.7	14.3	-	70.7

weather. The temperature during this season is uniformly high in the beginning of October but by November it begins to decrease more sharply and a cool weather sets in by December with temperature around 13.0°C.

Vegetation:

The Aligarh districts lies in the subtropical belt having deciduous type of vegetation. This district was once covered by dhak jungles which have been cleared for cultivation purpose. A certain amount of dhak jungles however are still found scattered in patches in the clayey and usar tracts. In the khaddar of Ganga, there is a considerable extent of tamarisk, an evergreen shrub on the more recent alluvium of the rivers. In the khaddar of Yamuna, there is a narrow belt of tamarisk which is followed by broad stretches of waste covered with that clung grass. The eastern, part of the district has more trees than the western part.

Soil:

The typical saucepan topography of Aligarh district has greatly helped in determining the character of soil. The soil of Aligarh district is alluvial (both old and new alluvium is found). The alluvium brought by the river Ganga spreads over about three fourth of the total area, while the alluvium brought by the river Yamuna spreads over about one fourth of the total area of the district. The new alluvium is confined to the flood plains of the rivers and their tributaries while the old alluvium is found in the level plain above the flood level of the main rivers and their tributaries. From the east of the river Ganga, the soil varies from sandy to sandy loam and clayey loam up to middle of the district. Further westwards there is again the

sandy loam tract which finally merges into the sandy bed of the river Yamuna.

Geological Classification of Soil:

The soils have been divided into two broad geological divisions.

1. Old alluvium or bhangar soil
2. New alluvium or khaddar soil

1. Bhangar Soil:

The Bhangar lands are found above the flood level of the main rivers and their tributaries. The most important material in bhangar lands is day, which at places becomes loam or sandy loam. In the clayey part of the alluvium, irregular kankar (nodules of calcium carbonate of various shapes and sizes) are formed due to transformation of calcareous materials of alluvial deposits into lumps or nodules. In areas where there is no proper surface drainage these salts keep on accumulating by leaching from the neighbouring regions. During the dry season, the soluble salts are sucked up in solution to the surface by capillary action and are deposited in the form of white efflorescence. In many parts of the district the slope of land is less than 20 cm to a kilometre and in some places there is complete lack of drainage, causing deposition of salts on the surface in the form of 'Reh'.

2. Khaddar Soil:

Khaddar lands are confined to the tracts and the flood plains of the rivers and their tributaries. They are formed by the main channels which are confined to well defined valley and the flood level of the water remains below the general level of the country side. The low level of the khaddar is in

conformity with the principal that as a river gets older, more and more of its deposits are found to be of a younger age and the bed of river sinks lower and so these younger deposits occupy lower levels than those occupied by earlier deposits. Khaddar lands are light coloured and poor in calcareous matter and are composed chiefly of sand, silt, mud and clay. They are generally free from kankar deposits.

Materials And Methods

MATERIALS AND METHODS

To study the cambial activity and production of secondary phloem and xylem, 24 normal 40 years old trees of each species were selected from local plantation. Cambial samples together with some sapwood and bark of 1-2 cm^2 size, were collected from main trunk at chest height, from the southern side of the tree using a chisel and hammer at fortnightly intervals for a period of two consecutive calendar years (2003 & 2004). Samples were collected from two trees on each turn. The next sets of samples were collected from the same set of trees at least after three months. Care was taken to collect samples at least 10 inches away from wounded spot, when the tree was used for second or third time.

To study the ontogenetic changes in cambium and its derivatives, five trees approximately thirty years old of comparable size and vigour, were selected for each species and five samples of bark with intact wood were collected as described above, at different heights from the base to the top of each tree. These collections were made once during the study period that is in 2004.

Fixation and preservation:

All the samples were fixed on the spot in F.A.A. (Formalin-Aceto-Alcohol) and after 72 hours duration preserved in 70% ethyl alcohol. To follow the seasonal and ontogenetic changes, the samples were sectioned on a Reichert's sliding microtome, at a thickness of 12-20 μm in transverse, tangential and radial longitudinal planes. The sections were then stained in different combinations of stains

and mounted in Canada balsam after dehydration in ethanol series.

Stains used:

Following stains were used alone and in combinations depending on the requirements.

A-For the study of bark and wood:

1. Heidenhain's Hematoxylin – Safranin (Johansen, 1940)
2. Heidenhain's Hematoxylin – Bismark brown (Johansen, 1940)
3. Tannic acid – Ferric chloride – Lacmoid (Cheadle et al, 1953).

B-For the study of cambium

1. Heidenhain's Hematoxylin
2. Tannic acid – Ferric chloride (Foster, 1934)

Maceration:

For the study of individual cells maceration is done. To macerate xylem and phloem, samples were cut in tangential slices at a thickness of approximately 0.5 to 1 mm. The slices were placed in a test tube and boiled in 20-40% nitric acid (HNO_3). After getting desired stage the slices were washed with distilled water and then treated with 5% aqueous solution of sodium hydroxide (NaOH) to neutralize the effect of HNO_3 and again carefully washed with distilled water. Small pieces of macerated material were placed on a slide in 5% aqueous glycerine after staining in different combinations, and teased apart with the help of needles or by tapping on the cover slip with a glass rod. Safranin and Bismark brown was used for the

study of xylem fibres, phloem fibres, vessel elements and lacmoid solution for sieve tube elements.

Quantitative estimation of the tissue:

The relative proportion of different types of elements was determined on the basis of the areas occupied by the respective elements in transverse and longitudinal planes with the help of Camera Lucida following the procedure describe by Ghouse & Iqbal (1975).

Measurements:

For each sample, macerated or sectioned 500 elements are measured on random basis with the help of an ocular micrometer scale under specific magnification of the compound microscope. Out of 500 readings, 25 different readings were taken into account and all the calculations done on the basis of them to summarize the vast amount of data. The mean and range of cell dimensions were determined after pooling the reading obtained from different sample. Rays of varying heights were measured and categorized as short (up to 300 μm), medium (301 to 600 μm) and tall (above 600 μm) where as width wise rays categorized as uniseriate, biseriate and multiseriate.

Statistical analysis:

Observations recorded on various parameters are subjected to statistical analysis.

1. Range: The first value represents the lower limit and second one higher limit of observations in different sets of data.

2. Arithmetic mean: The arithmetic mean is computed by summing up the observations and dividing the total by number of observations. Symbolically,

$$\bar{X} = \frac{X_1 + X_2 + X_3 \ldots\ldots X_n}{n}$$

or $$\bar{X} = \frac{\Sigma_x}{n}$$

Where,

$\bar{X}$ = arithmetic mean

Σx = sum of all values of the variable, X i.e. X_1, X_2, X_3... X_n

n = number of observations

3. Standard deviation (SD):

It is the measure of variability of dispersion which is the positive square root of mean of the deviation of the individual observations from their arithmetic mean, or, in other words, the square of the standard deviation is equal to the mean of the squares of the deviation of individual observations from their arithmetic mean.

So square of standard deviation

$$SD^2 = \frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + (X_3 - \bar{X})^2 + \ldots.(X_n - \bar{X})^2}{n}$$

$$SD = \sqrt{\frac{(X_1 - \bar{X})^2 + (X_2 - \bar{X})^2 + (X_3 - \bar{X})^2 + \ldots.(X_n - \bar{X})^2}{n}}$$

Where,

$X_1, X_2, X_3, \ldots.X_n$ = individual observations

$\bar{X}$ = arithmetic mean

n = total number of observations

4. Standard error of the Mean (SE):

The standard deviation computed for sample mean is called by the name standard error of mean. This is calculated by the following formula.

$$\pm SE = \frac{SD}{\sqrt{n}}$$

Where,

SD = Standard deviation of individual observations

n = Total number of observations

5. Coefficient of Variation (CV):

It measures the relative magnitude of variations present in observations and is related to the magnitude of their arithmetic mean. It is defined as the ratio of standard deviation to arithmetic mean and is expressed in percentage.

The following formula was applied to compute coefficient of variation (CV) –

$$CV = \frac{S.D.}{X} \times 100$$

Where, SD = Standard deviation of sample

$\bar{X}$ = Arithmetic mean

6. Analysis of variance (ANOVA):

It is used for computing mean difference amongst more than two groups.

Construction of data table:

Rows / Columns	t_1	t_2	t_3	t_4	T_5	T_6	Total
r_1	1	6	11	16	21	26	$1+..26=R_1$
r_2	2	7	12	17	22	27	$2+..27=R_2$
r_3	3	8	13	18	23	28	$3+..28=R_3$
r_4	4	9	14	19	24	29	$4+..29=R_4$
r_5	5	10	15	20	25	30	$5+..30=R_5$
Total	$1+..5$ T_1	$6+..10$ T_2	$11+..15$ T_3	$16+..20$ T_4	$21+..25$ T_5	$26+..30$ T_6	$T_1+..T_6=$ G.T.

Correction factor (C.F.) $= \frac{(G.T.)^2}{txr}$

Where,

G.T. = Grand total

t = No. of columns

r = No. of rows

Row Sum of Squares (R.S.S.):

$$R.S.S. = \frac{R_1^2+R_2^2+R_3^2+R_4^2+R_5^2}{t} - C.F.$$

Column Sum of Squares (C.S.S.):

$$C.S.S. = \frac{T_1^2+T_2^2+T_3^2+T_4^2+T_5^2}{r} - C.F.$$

Total Sum of Squares (T.S.S.)

$$T.S.S. = (1^2+2^2+3^2+4^2+5^2+.....30^2) - C.F.$$

Error Sum of Squares (E.S.S.)

$$E.S.S. = T.S.S. - (R.S.S. + C.S.S.)$$

Construction of ANOVA table:

Sources of variation	Sum of Squares (S.S.)	Degree of Freedom	Mean Sum of Squares (M.S.S.)	Variance Ratio (F)
Rows	R.S.S.	(r – 1)	RSS/DF	MSS/MSE
Columns	C.S.S.	(t – 1)	CSS/DF	MSS/MSE
Error	E.S.S.	(r –1) (t – 1)	ESS/ DF = MSE	
Total				

Results:

By comparing these values with the tabulated value of variance ratio (F) for respective degree of freedom (df) and at certain level of significance, the null hypothesis of the homogeneity of various treatments and various varieties may be rejected or accepted.

Observations

OBSERVATIONS

Structure of cambium:

In all the three investigated species the vascular cambium forms a continuous cylinder between the xylem and phloem in the tree trunk. It consists of two types of initials, spindle shaped elements with tapering end walls, the fusiform initials, and the almost isodiametric or rectangular ray initials. The fusiform initials appear roughly hexangular in tangential sections with tapering ends, which overlap to a considerable extent except *C. pentandra*. The arrangement of the different components of cambium thus leads to the formation of semi- stratified structure in *C. pentandra*, typical non-stratified in *F. glomerata* and *M. oleifera*.

The walls of the fusiform initials bear primary pit fields and have distinct plasmodesmata connections with the contiguous elements, especially with the ray initials. The radial walls of fusiform initials are slightly thicker than the tangential ones and appear distinctly beaded during dormancy (Plates-III-F, IV-D,E, V-D,E,F, VI-C,D).

The length of fusiform cells varies from 212.50 - 712.50 μm in *C. pentandra*, 150.00 - 612.50 μm in F. *glomerata* and 125.00 - 437.50 μm in *M. oleifera* and their tapering ends are found to vary from 25.00 - 112.5 μm, 37.50 - 237.50 μm and 25.00 - 125.00 μm respectively. The width of fusiform initials is found varying from 18.75 - 43.75 μm in *C. pentandra*, 18.75 - 37.50 μm in *F. glomerata* and 31.25 - 62.50 μm in *M. oleifera* (Table 2). The longest fusiform initials have been found in *C. pentandra* and widest in *M. oleifera* among the three

investigated species. The ray initials aggregate in distinct groups and from cambial rays which vary in width and height to a considerable extent in different species (Table 2).

The width of cambial rays varies from 1-9 cells in *C. pentandra*, 1-20 cells is *F. glomerata* and 1-3 cells in *M. oleifera*, while their height varies from 1-66 cells in *C. pentandra*, 1-55 cells in F. glomerata and 1-18 cells in *M. oleifera* (Table 2).

Analysis of the data of dimensional variations of ray initials revealed that the anticlinal and periclinal diameter of these initials ranges from 10.50/7.00 - 73.50/56.00 μm in *C. pentandra*, 7.00/3.50 - 56.00/28.00 μm in F. glomerata and 14.00/7.00 - 56.00/45.00 μm in *M. oleifera* (Table 2).

The cambial rays have been classified into three groups based on their height viz. - short (up to 300 μm), medium (301 - 600 μm) and tall (above 600 μm). The rays of different height occur in different proportions. In all three species investigated percentage of short rays dominate over the medium and tall rays and found to constitute about 50% in *C. pentandra*, 63% in *F. glomerata* and 81% in *M. oleifera* (Fig.1). Similarly the width of rays also varies in different species, the uniseriate rays in *C. pentandra* are about 37% of the total number of rays in a unit area, while in *F. glomerata* and *M. oleifera* uniseriate rays constitute about 20% and 28% respectively. In a similar count biseriate rays constitute about 19% of the total count in *C. pentandra*, 18% in *F. glomerata* and 62% in *M. oleifera*, while the multiseriate rays constitute about 44%, 62% and 10% respectively (Fig.2). Depending upon the cambial make up, the ratio of ray and fusiform initials differ in different species. In *C. pentandra* the ray initials constitute about 44% of the cambial zone, in *F. glomerata* 37% and in *M. oleifera* 33% (Fig.3).

Table-2: Anatomical data (based on round year collections) on the variations of cambial cell size and structure in some selected species.

Species		Fusiform Initials			Ray Initials		Cambial Rays	
		Length (μm)	Width (μm)	Length of Tapering Ends (μm)	Anticlinal Diameter (μm)	Periclinial Diameter (μm)	Height in Cells	Width in Cells
C. pentandra	Range	212.50-712.50	18.75-43.75	25.00- 112.50	10.50- 73.50	7.00- 56.00	1 – 66	1 – 9
	Mean±S.E.	346.58 ±3.27	34.85 ±0.33	62.00 ±0.92	30.85 ±0.71	26.86 ±0.57		
	S.D.	56.62	5.68	15.86	12.35	9.92		
	C.V.%	16.33	16.29	25.58	40.03	36.94		
F. glomerata	Range	150.00- 612.50	18.75-37.50	37.50- 237.50	7.00- 56.00	3.50- 28.00	1 – 55	1 – 20
	Mean±S.E.	330.71 ±5.38	26.75 ±0.23	93.78 ±3.34	18.27 ±0.44	14.74 ±0.27		
	S.D.	93.25	3.90	57.72	7.68	4.75		
	C.V.%	28.19	14.58	61.55	42.03	32.26		
M. oleifera	Range	125.00- 437.50	31.25-62.50	25.00- 125.00	14.00- 56.00	7.00- 45.00	1 – 18	1 – 3
	Mean±S.E.	277.21 ±2.87	41.83 ±0.25	74.58 ±0.87	33.98 ±0.54	27.46 ±0.41		
	S.D.	49.71	4.27	15.02	9.40	7.02		
	C.V.%	17.93	10.21	20.14	27.67	25.56		

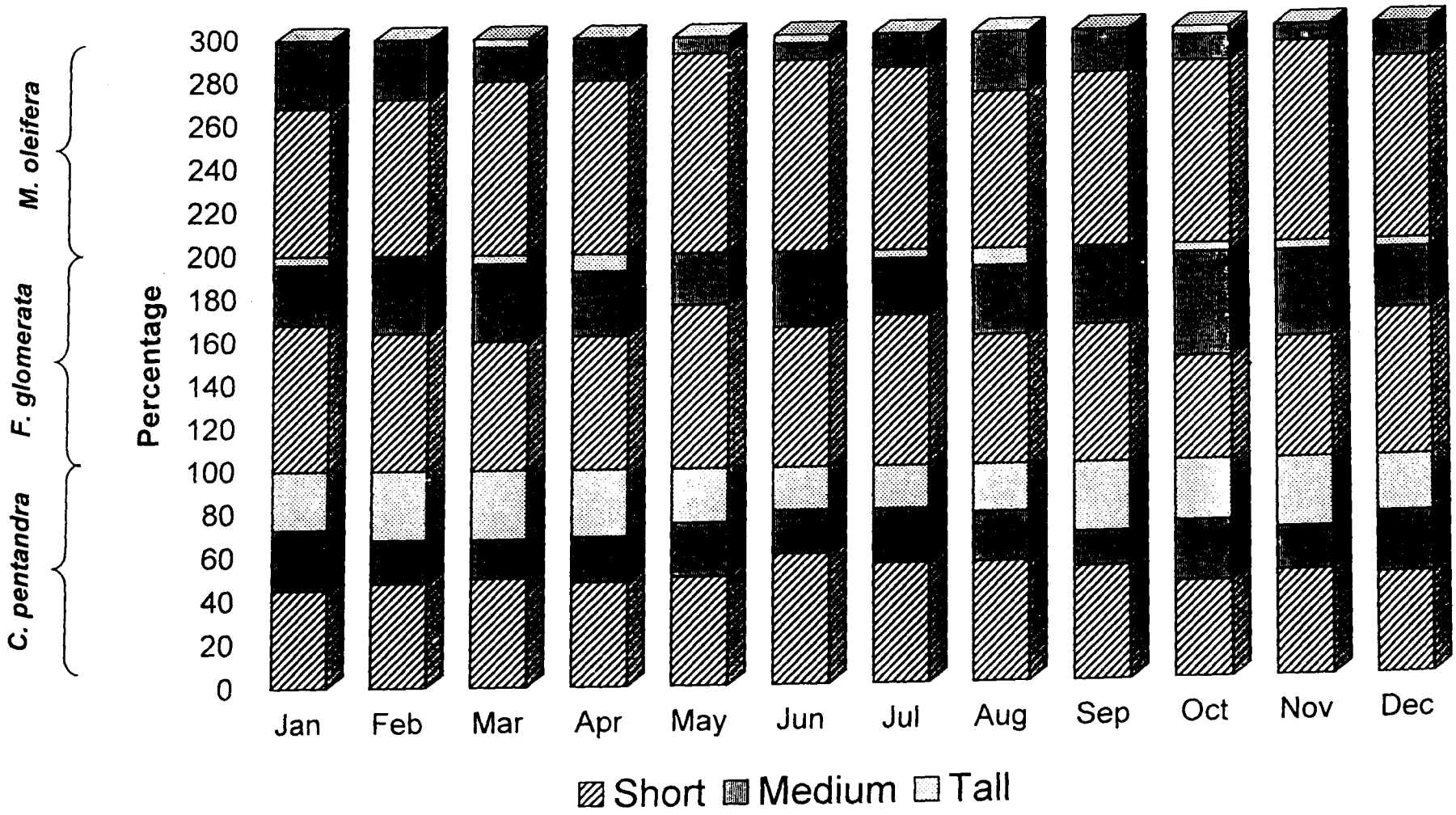


Figure-1: Percent cambial rays.

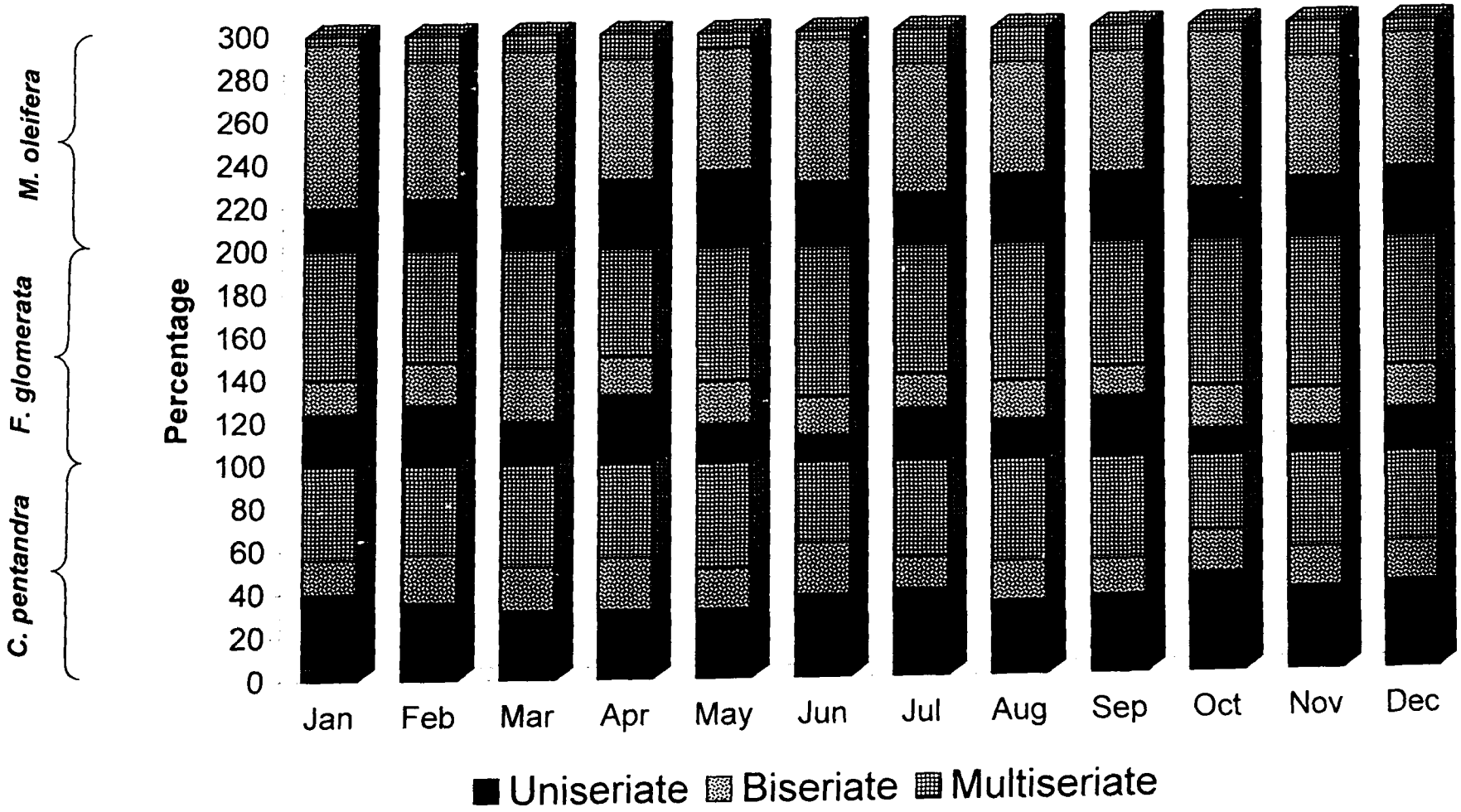


Figure-2: Percent cambial rays.

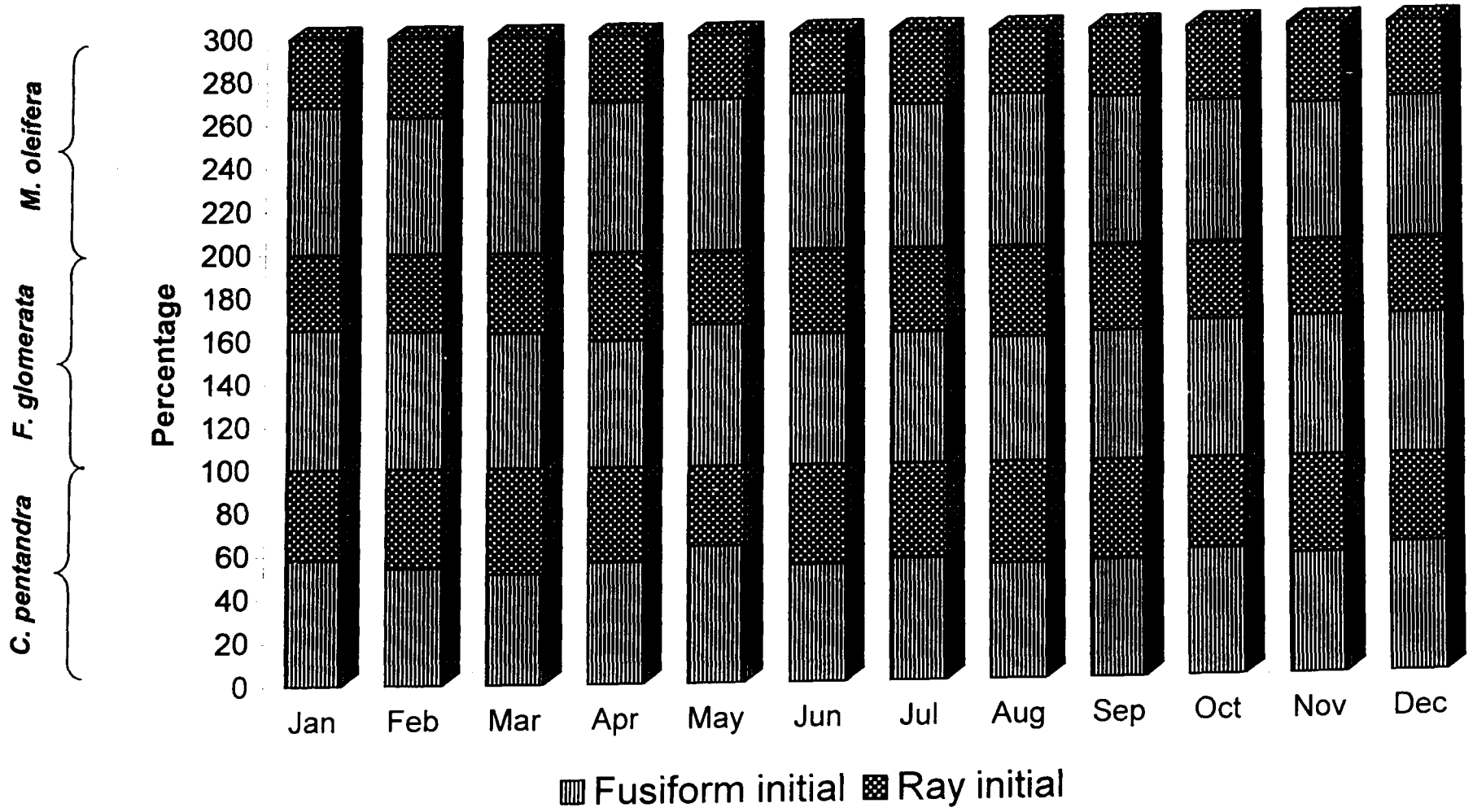


Figure-3: Percent tangential area (cambium).

Developmental changes in the structure of cambium:

The development of the vascular cambium starts at the basal internode in the growing shoots and proceeds acropetally towards the apex. The differentiation of cambial initials which occurs at different loci in the fascicular regions and later spreads laterally to form a ring of cambium. The changes in the cambial structure regarding the size of the different components and their relative proportion in tangential plane and number of cambial layers in transverse plane have been analyzed in the shoot axis of varying age and size. In transverse sections of the young shoots, the cambial zone consists of 4-5 layers of cambial cells in *F. glomerata,* 4-7 layers in *C. pentandra* and *M. oleifera* while the number of cambial layers in the adult trees varies from 4-19, 3-20 and 5-13 respectively.

In tangential longitudinal sections it is observed that the fusiform initials undergo considerable size variation with the growing girth of the stem axis. The length of fusiform initials shows an increasing trend from top toward the base of the tree in *C. pentandra* and in *F. glomerata* initially it increases and exhibit declining trend at the base while in *M. oleifera* the length exhibits increasing tendency with the advancing age and sooner gets stabilised near the base (Tables 3-5). The rate of increase in length of fusiform initials appears to be high in young shoots and low in older regions of the axis in all the species investigated. It appears, therefore, that the ability of newly formed initials to elongate in size depends on the age of the meristem. This increase in the length average of fusiform initials goes up to 24% in *C. pentandra*, 23% in *F. glomerata* and 46% in *M. oleifera* respectively.

Table-3: Changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Ceiba pentandra*.

Circumference of the axis in Cm.	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	262.50-400.00	289.50 ±7.75	38.74	13.38	25.00-37.50	25.75 ±1.03	5.14	19.97	37.50-62.50	48.50 ±1.50	14.10	15.46
55	250.00-437.50	328.50 ±9.83	49.15	14.96	25.00-37.50	30.00 ±1.03	5.13	17.10	37.50-87.50	50.00 ±2.43	12.14	24.28
80	262.50-400.00	343.50 ±7.78	38.88	11.32	25.00-37.50	32.25 ±1.18	5.90	18.28	37.50-62.50	51.00 ±1.76	8.78	17.22
105	300.00-425.00	358.50 ±7.17	35.85	10.00	25.00-37.50	31.75 ±1.19	5.96	18.78	37.50-87.50	56.00 ±2.36	11.79	21.06
150	300.00-400.00	360.00 ±4.51	22.53	6.26	18.75-37.50	30.25 ±1.38	6.91	22.85	37.50-100.00	65.50 ±2.82	14.11	21.53
F=3.43, p<0.01					F=2.01, p is non significant				F=10.52, p<0.01			

Table-4: Changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Ficus glomerata*.

Circumference of the axis in Cm.	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	150.00-400.00	272.00 ±12.89	64.46	23.70	25.00-31.25	24.00 ±0.54	2.72	11.35	62.50-100.00	79.50 ±2.38	11.90	14.97
55	187.50-400.00	293.50 ±12.37	61.86	21.07	25.00-37.50	26.00 ±0.85	4.24	15.85	50.00-112.50	81.50 ±3.83	19.13	23.48
80	150.00-425.00	301.00 ±15.63	78.16	25.97	25.00-37.50	26.25 ±0.72	3.61	13.75	50.00-125.00	82.00 ±5.00	25.02	30.51
105	175.00-525.00	337.00 ±14.78	73.91	21.93	25.00-37.50	25.50 ±0.50	2.50	9.80	50.00-175.00	92.50 ±5.59	27.95	30.22
150	200.00-512.50	305.00 ±19.42	97.09	31.83	25.00-37.50	26.50 ±0.75	3.73	14.09	50.00-125.00	83.50 ±4.19	20.95	25.09
F = 1.83, p is non-significant					F = 0.49, p is non-significant				F = 1.36, p is non-significant			

Table-5: Changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Moringa oleifera*.

Circumference of the axis in Cm.	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	187.50-300.00	198.00 ±6.58	32.90	16.62	31.25-43.75	39.50 ±0.78	3.92	9.92	37.50-10000	55.50 ±3.22	16.09	28.97
55	187.50-287.50	242.00 ±4.32	21.61	8.93	37.50-43.75	40.00 ±0.63	3.13	7.81	50.00-100.00	62.50 ±2.39	11.96	19.15
80	187.50-375.00	286.50 ±8.38	41.91	14.63	37.50-50.00	42.25 ±0.65	3.27	7.73	50.00-112.50	72.00 ±3.00	15.00	20.83
105	175.00-375.00	289.50 ±8.80	44.00	15.20	25.00-50.00	41.25 ±0.95	4.77	11.57	62.50-100.00	76.50 ±2.20	11.02	14.40
150	225.00-412.50	281.00 ±8.23	41.16	14.65	37.50-50.00	41.00 ±0.73	3.64	8.89	62.50-100.00	76.00 ±2.38	11.92	15.69
	F = 10.02, p<0.01				F = 2.03, p is non-significant				F = 0.96, p is non-significant			

Analysis of the data obtained on the width of fusiform initials has revealed that in *C. pentandra* the width initially increases and later exhibits a declining trend at the base. In *F. glomerata* and *M. oleifera* width of fusiform initials shows a slight increase with age and soon gets more or less stabilised (Tables 3-5).

Measurement of the tapering ends of the fusiform initials revealed that their size increases from top towards the base in *C. pentandra*, in *F. glomerata* the length of tapering ends first increases with increase in stem girth and then declines at the base, while in *M. oleifera* the length of tapering ends first increases with increase in stem girth and soon gets stabilized (Tables 3-5).

A similar analysis of the ray initials of *C. pentandra* and *F. glomerata* both anticlinal and periclinal diameters first exhibit an increasing trend which is followed by a declining tendency with the average varying from 23.24/18.90 - 26.88/22.54 μm and 19.32/15.40 - 23.38/17.78 μm respectively. In *M. oleifera* both anticlinal and periclinal diameters increase with increase in the girth of the stem axis with an average ranging from 24.64/19.04 - 35.28/29.54 μm (Tables 6-8).

Thus, ray initials are found to undergo dimensional variations in different ways in different species investigated and it may be concluded that the mode of dimensional variation may be a species specific character. The ray initials are also found to undergo multiplication (Figs. 4&5). As a consequence of the above changes in the makeup of cambium, ray initials are found to occupy a relatively greater area in the

Table-6: Changes in the cell size of ray initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Ceiba pentandra*.

Circumference of the axis in Cm.	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	14.00-35.00	23.66±1.34	6.72	28.42	10.50-28.00	18.90±1.16	5.80	30.71
55	14.00-42.00	26.60±1.51	7.56	28.42	7.00-42.00	21.14±1.43	7.18	33.96
80	14.00-49.00	26.88±1.83	9.13	33.98	10.50-42.00	22.54±1.80	8.98	39.86
105	10.50-38.50	24.36±1.60	7.99	32.78	10.50-45.50	22.26±1.96	9.79	43.98
150	7.00-52.50	23.24±2.00	10.00	43.01	7.00-45.50	21.98±1.97	9.87	44.93
F = 1.02, p is non-significant					F = 0.76, p is non-significant			

Table-7: Changes in the cell size of ray initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Ficus glomerata*.

Circumference of the axis in Cm.	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	10.50-28.00	19.46±1.09	5.45	28.00	7.00-28.00	15.54±1.07	5.35	34.45
55	10.50-31.50	19.32±1.30	6.48	33.53	7.00-28.00	15.40±1.07	5.35	34.72
80	10.50-31.50	21.56±1.12	5.60	25.96	10.50-31.50	17.78±1.12	5.62	31.60
105	14.00-31.50	23.38±1.02	5.12	21.92	10.50-24.50	17.50±0.78	3.91	22.36
150	14.00-28.00	20.02±1.02	5.10	25.49	7.00-28.00	16.94±1.06	5.32	31.38
$F = 2.38, p<0.05$					$F = 1.15$, p is non-significant			

Table-8: Changes in the cell size of ray initials (as seen in tangential longitudinal sections) along the tree axis of varying girth in *Moringa oleifera*.

Circumference of the axis in Cm.	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	14.00-42.00	24.64±1.51	7.53	30.54	10.50-28.00	19.04±1.07	5.35	28.12
55	21.00-52.50	31.36±1.46	7.32	23.34	10.50-35.00	22.68±1.47	7.36	32.47
80	17.50-49.00	33.32±1.76	8.82	26.46	14.00-35.00	25.06±1.30	6.52	26.03
105	17.50-49.00	35.14±1.55	7.73	21.99	14.00-35.00	28.00±1.16	5.80	20.73
150	21.00-52.50	35.28±1.56	7.82	22.17	14.00-42.00	29.54±1.26	6.32	21.38
		F = 7.79, $p<0.01$				F = 11.06, $p<0.01$		

cambial cylinder in the old trees as compared to younger ones (Fig.6).

With the advancing age of the plant axis, the cambial cylinder also expands by adding more cells. The fusiform initials undergo pseudo-transverse divisions and give rise to sister initials (Plates- I-F, III-D,E, IV-A,C,D,E,F, V-C, VI-B). Similarly, the ray initials also divide and give rise to new ray initials. All this happens in order to cope with the expansion of the axis. The ray initials are also produced by the fusiform initials and this happens either by the transverse segmentation of the fusiform cells or by the formation of new initials as terminals or lateral segments (Plates- I-C, III-D, IV-A,E).

The rays are also found fusing with one another to form tall and wider bodies (Plates- I-A, II-A,C, IV-A,C). This is brought about by the conversion of the intervening fusiform initials into a group of ray initials. The newly produced rays having a limited height in the beginning grow into tall structure by the division of the existing initial. On the other hand fusiform initials are also found to intrude into a panel of ray initials, resulting in the division of a broad or tall ray into a number of smaller entities (Plates- I-D, IIB,C, III-B).

The vascular cambium undergoes constant changes in its composition as an accommodative measure to meet the increasing circumference of the cylinder. This usually resulted in a considerable change in the corresponding volume of the different initials. In the young shoot, the fusiform initials have been found to occupy about 68% of the total area of the cambial cylinder in *C. pentandra*, 69% in *F. glomerata* and 58% in *M. oleifera,* while the mature trunks the corresponding area of fusiform initials is found 54% in *C. pentandra*, 59% in

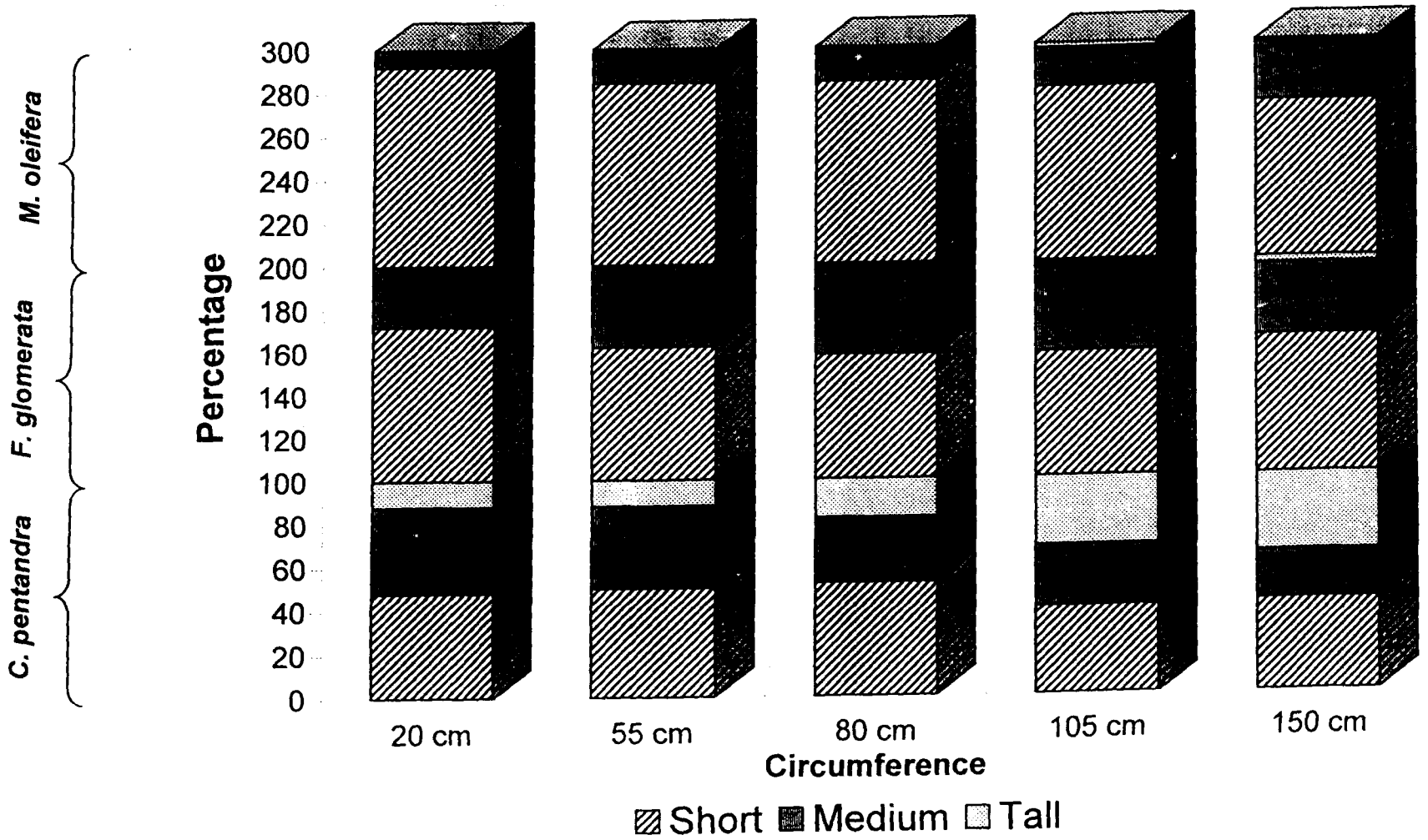


Figure-4: Percent cambial rays.

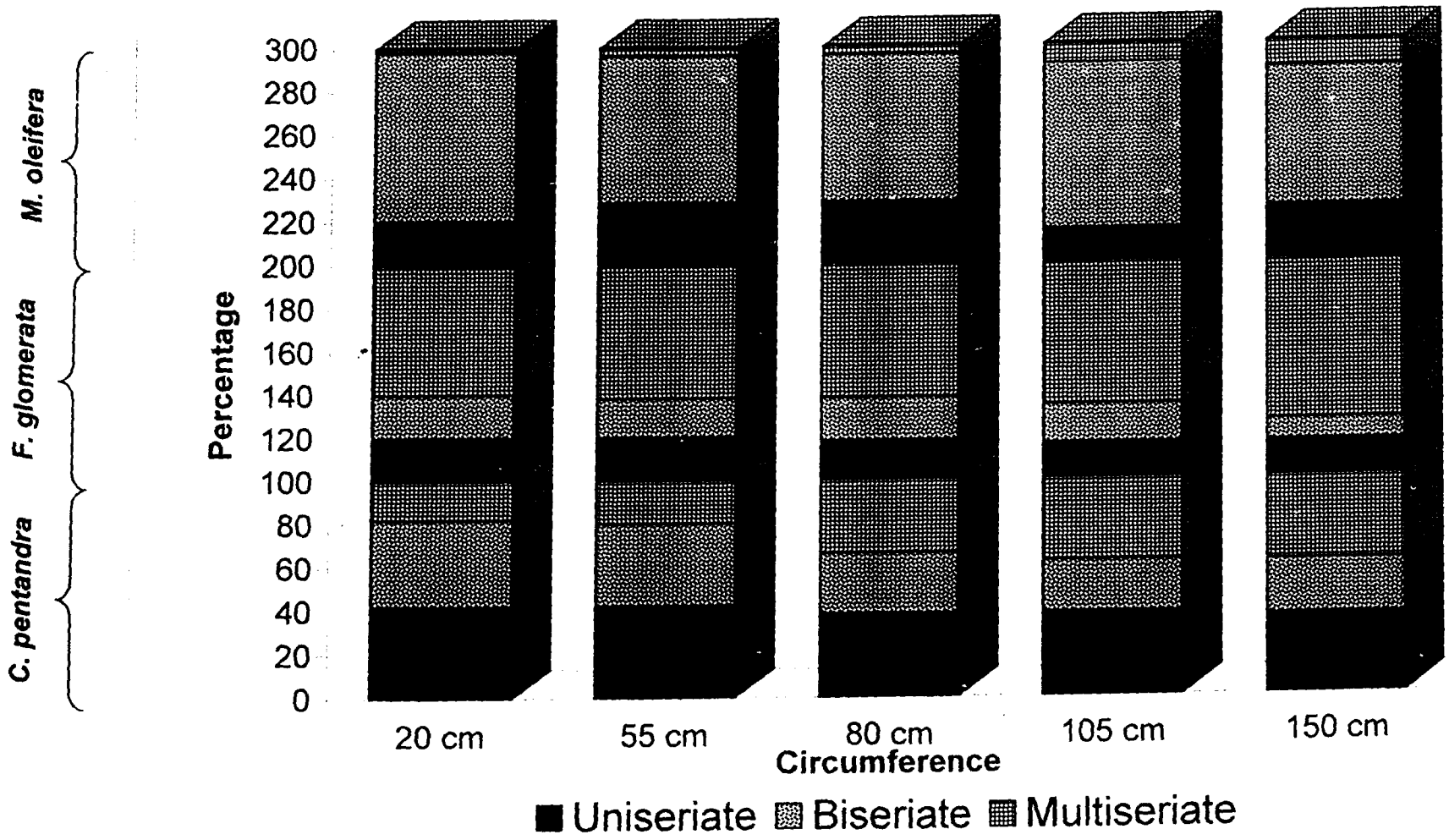


Figure-5: Percent cambial rays.

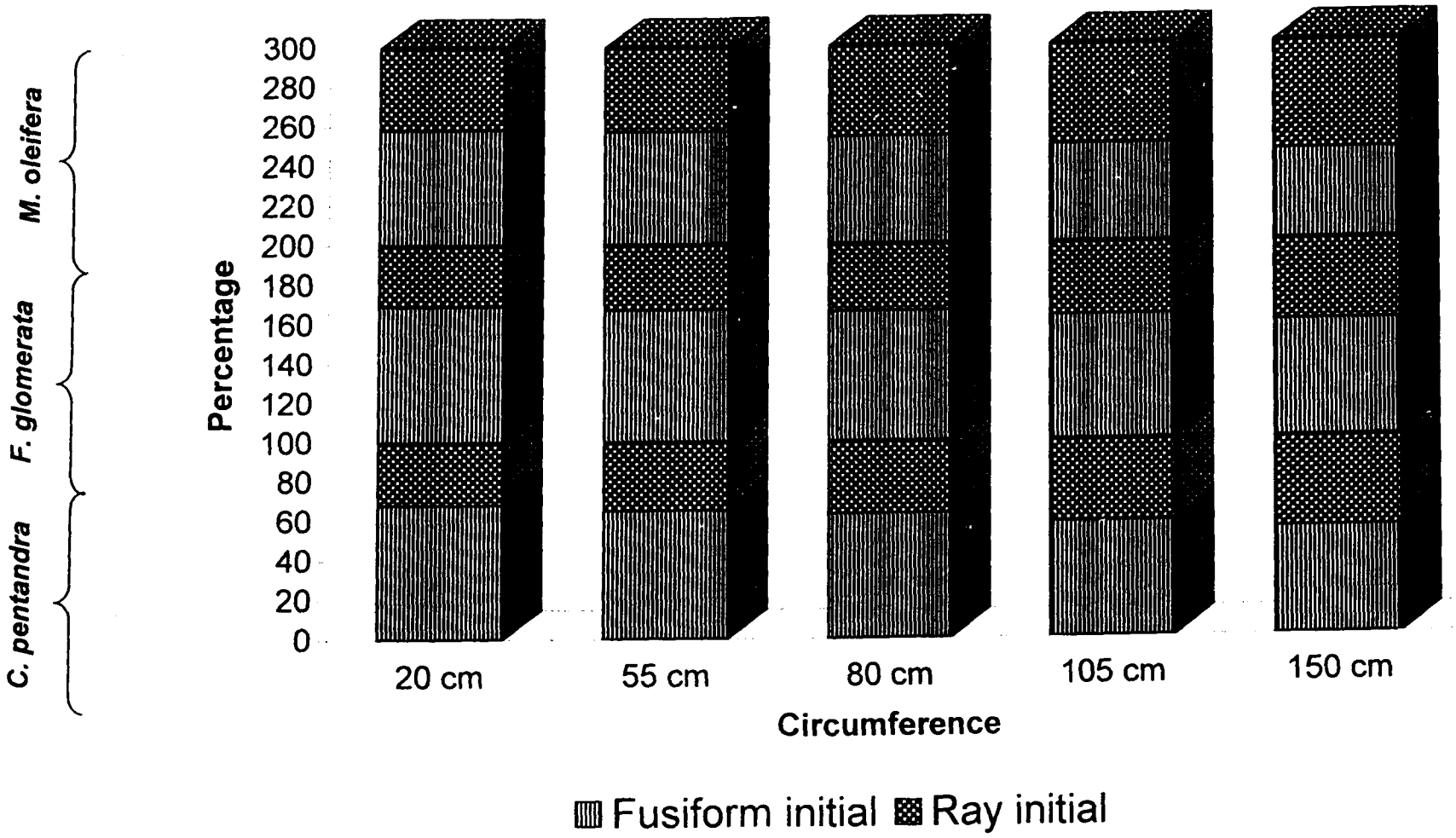


Figure-6: Percent tangential area (cambium).

F. glomerata and 45% in *M. oleifera* (Fig.6). Thus in mature trunks the corresponding area of ray initials shows significant increase with the increasing age of the plant axis and extent of expansion of rays in older axes is found 43% in *C. pentandra*, 32% in *F. glomerata* while 31% in *M. oleifera* (Fig.6).

Seasonal changes in the structure of cambium:

The fusiform as well as the ray initials exhibit certain changes in their characteristics under different climatic conditions. In *C. pentandra*, the average length and width of fusiform initials is found varying from 319.50-363.50 μm and 29.25 - 39.25 μm, while the average size of tapering ends ranges from 51.00 - 71.50 μm (Table 9). The dimension of ray initials also exhibit minor variations in different season. The mean value of the anticlinal and periclinal diameters varies from 24.36/21.98 - 34.02/30.10 μm during a calendar year (Table 10). In *F. glomerata* the average length and width of fusiform initials ranges from 280.00 - 430.00 μm and 26.00 - 29.25 μm respectively and length of tapering ends varies from 82.00 - 112.00 μm (Table 11). Similarly anticlinal and periclinal diameters of ray initials, average varies from 14.00/13.02 - 22.54/17.22 μm in different months (Table 12). In *M. oleifera,* the average length and width of fusiform initials ranges from 255.00 - 309.00 μm and 39.50 - 46.00 μm respectively. The size of tapering ends varies from 62.50-85.00 μm (Table 13). The mean value of anticlinal and periclinal diameters of ray initials varies from 23.80/22.82 - 39.90/31.92 μm (Table 14).

Further studies concerning to the structure of rays, mode of development, proportional percentage of different types of rays and area occupied by them in tangential plane during a calendar year has revealed that their size as well as their development appears to be influenced by the seasonal conditions. The short rays occur more frequently in June, July, and August and medium in January, October and December

Table-9: Seasonal changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) of cambial zone in *Ceiba pentandra*.

Months	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	275.00-462.50	334.00 ±8.88	44.42	13.30	31.25-43.75	37.25 ±0.44	2.19	5.90	25.00-62.50	59.50 ±1.43	7.14	12.01
February	300.00-400.00	360.00 ±4.51	22.53	6.26	18.75-37.50	30.25 ±1.38	6.91	22.85	37.50-62.50	51.00 ±1.76	8.78	17.22
March	212.50-387.50	329.00 ±9.57	47.83	14.54	37.50-43.75	37.75 ±0.25	1.25	3.31	25.00-62.50	60.50 ±1.73	8.63	14.26
April	250.00-412.50	363.50 ±9.30	46.48	12.79	37.50-43.75	38.50 ±0.47	2.34	6.07	37.50-112.50	71.50 ±4.36	21.81	30.50
May	250.00-612.50	361.00 ±17.43	87.15	24.14	37.50-43.75	39.25 ±0.57	2.86	7.30	37.50-100.00	61.50 ±3.53	17.65	28.70
June	275.00-475.00	340.00 ±9.71	48.55	14.28	31.25-43.75	38.25 ±0.66	3.29	8.60	50.00-112.50	71.00 ±3.04	15.19	21.39
July	225.00-462.50	350.50 ±14.28	71.40	20.37	37.50-43.75	39.00 ±0.54	2.72	6.99	37.50-87.50	65.50 ±2.73	13.64	20.82
August	225.00-500.00	319.50 ±11.16	55.79	17.46	25.00-37.50	29.50 ±0.77	3.84	13.00	37.50-87.50	59.00 ±2.75	13.75	23.31
September	225.00-500.00	347.50 ±12.64	63.22	18.19	18.75-37.50	29.50 ±1.33	6.63	22.49	50.00-75.00	61.00 ±2.08	10.40	17.06
October	312.50-387.50	358.00 ±4.38	21.91	6.12	25.00-37.50	29.25 ±0.93	4.68	15.99	37.50-62.50	55.50 ±1.18	5.91	10.64
November	262.50-450.00	335.00 ±10.43	52.17	15.57	31.25-37.50	36.50 ±0.47	2.34	6.41	37.50-87.50	61.50 ±2.97	14.84	24.13
December	312.50-500.00	361.00 ±10.23	51.15	14.17	25.00-37.50	33.25 ±1.13	5.63	16.92	50.00-112.50	66.50 ±3.29	16.43	24.70
	F = 3.77, p<0.01				F = 25.52, p<0.01				F = 10.62, p<0.01			

Table-10: Seasonal changes in the cell size of ray initials (as seen in tangential longitudinal sections) in the cambial zone in *Ceiba pentandra*.

Months	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	14.00-70.00	33.04±2.44	12.21	36.97	14.00-38.50	29.40±1.54	7.69	26.17
February	10.50-38.50	24.36±1.60	7.99	32.78	7.00-45.50	21.98±1.97	9.87	44.93
March	17.50-70.00	33.32±2.79	13.93	41.81	14.00-49.00	27.72±1.86	9.31	33.59
April	17.50-52.50	32.62±2.33	11.64	35.68	14.00-45.50	28.84±1.89	9.44	32.73
May	10.50-73.50	29.26±2.73	13.63	46.57	14.00-45.50	24.08±1.75	8.77	36.41
June	14.00-52.50	31.92±2.23	11.13	34.86	10.50-42.00	28.00±1.73	8.63	30.83
July	17.50-59.50	32.48±2.07	10.33	31.80	10.50-38.50	26.74±1.37	6.84	25.59
August	14.00-70.00	33.74±.3.20	16.00	47.43	14.00-45.50	27.40±1.99	9.93	36.20
September	10.50-70.00	31.08±2.91	14.55	46.81	7.00-56.00	27.02±2.48	12.40	45.88
October	14.00-49.00	29.82±2.26	11.30	37.90	10.50-56.00	30.10±2.36	11.78	39.15
November	14.00-52.50	34.02±2.11	10.53	30.94	14.00-52.50	27.58±2.11	10.56	38.30
December	10.50-49.00	24.50±2.08	10.40	42.46	7.00-45.50	23.38±2.21	11.06	47.28
F = 1.88, p >0.05					F = 1.59, p is non-significant			

Table-11: Seasonal changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) of cambial zone in *Ficus glomerata*.

Months	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	212.50-500.00	324.00 ±14.50	72.48	22.34	25.00-37.50	27.25 ±0.80	3.99	14.63	50.00-150.00	82.50 ±5.00	25.00	30.30
February	200.00-512.50	305.00 ±19.42	97.09	31.83	25.00-37.50	26.50 ±0.75	3.73	14.09	50.00-125.00	83.50 ±4.19	20.95	25.09
March	150.00-525.00	322.00 ±20.90	104.48	32.45	25.00-31.25	26.00 ±0.46	2.34	9.00	62.50-162.50	92.00 ± 4.94	24.71	26.86
April	187.50-437.50	296.50 ±12.43	62.14	20.96	25.00-37.50	26.25 ±0.63	3.13	11.90	62.50-125.00	87.00 ±3.57	17.85	20.52
May	225.00-437.50	309.00 ±11.29	56.43	18.26	25.00-37.50	29.25 ±1.07	5.33	18.21	62.50-137.50	96.00 ±4.03	20.13	20.97
June	175.00-475.00	285.00 ±15.90	79.52	27.85	25.00-37.50	26.25 ±0.72	3.61	13.75	37.50-112.50	82.00 ±3.96	19.79	24.13
July	225.00-525.00	357.00 ±17.09	85.47	23.91	25.00-37.50	26.75 ±0.77	3.84	14.34	62.50-175.00	105.00 ± 5.00	25.00	23.81
August	225.00-500.00	382.00 ±15.31	76.55	20.04	25.00-37.50	26.25 ±0.72	3.61	13.75	62.50-162.50	93.50 ±3.96	19.80	21.18
September	187.50-400.00	280.00 ±10.97	54.85	19.56	25.00-37.50	27.25 ±0.95	4.73	17.37	50.00-137.00	85.00 ±4.56	22.82	26.85
October	225.00-712.50	430.00 ±25.41	127.07	29.55	18.75-37.50	27.00 ±0.94	4.68	17.32	50.00-187.50	101.00 ±6.93	34.66	34.32
November	225.00-512.50	366.00 ±15.82	79.10	21.61	25.00-37.50	26.25 ±0.72	3.61	13.75	62.50-237.50	112.00 ±7.52	37.58	33.56
December	175.00-400.00	310.00 ±9.42	47.09	15.19	25.00-37.50	26.00 ±0.59	2.95	11.36	75.00-137.50	105.90 ±3.94	19.32	18.25
	F = 9.38, p<0.01				F = 1.04, p non-significant				F = 2.37, p<0.01			

Table-12: Seasonal changes in the cell size of ray initials (as seen in tangential longitudinal sections) in the cambial zone in *Ficus glomerata*.

Months	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	7.00-24.50	14.00±0.99	4.95	35.36	3.50-28.00	13.02±1.04	5.20	39.96
February	14.00-28.00	20.02±1.02	5.10	25.49	7.00-28.00	16.94±1.06	5.32	31.38
March	7.00-28.00	15.82±1.30	6.48	40.95	3.50-28.00	13.16±1.11	5.56	42.25
April	7.00-52.50	20.58±2.36	11.80	57.32	7.00-28.00	14.28±0.97	4.84	33.87
May	7.00-24.50	15.54±0.81	4.05	26.07	7.00-21.00	15.26±0.70	3.48	22.82
June	10.50-24.50	17.08±0.71	3.54	20.76	14.00-24.50	17.08±0.55	2.73	16.00
July	10.50-28.00	19.46±0.88	4.41	22.68	7.00-24.50	15.40±0.88	4.40	28.60
August	7.00-42.00	18.90±1.50	7.49	39.65	7.00-21.00	13.86±0.84	4.22	30.48
September	7.00-45.50	18.76±1.95	9.74	51.90	7.00-28.00	13.30±0.93	4.63	34.81
October	7.00-56.00	19.46±1.91	9.54	49.00	3.50-24.50	13.58±0.95	4.77	35.15
November	10.50-52.50	22.54±2.21	11.07	49.12	10.50-28.00	17.22±1.11	5.53	32.09
December	7.00-28.00	17.08±0.95	4.77	27.95	7.00-17.50	13.72±0.64	3.18	23.19
F = 2.27, p<0.01					F = 3.05, p <0.01			

Table-13: Seasonal changes in the cell size of fusiform initials (as seen in tangential longitudinal sections) of cambial zone in *Moringa oleifera*.

Months	Length of Fusiform Initials (μm)				Width of Fusiform Initials (μm)				Tapering Ends of Fusiform Initials (μm)			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	187.50-400.00	292.50 ±11.43	57.17	19.54	37.50-50.00	42.50 ±0.72	3.61	8.49	25.00-93.75	62.50 ±2.39	11.97	19.15
February	225.00-412.50	281.00 ±8.23	41.16	14.65	31.25-43.75	39.50 ±0.78	3.92	9.92	62.50-100.00	76.00 ±2.38	11.92	15.69
March	225.00-337.50	274.00 ±6.53	32.66	11.92	37.50-50.00	42.25 ±0.75	3.73	8.83	37.50-87.50	65.50 ±2.61	13.05	19.92
April	137.50-375.00	269.00 ±11.93	59.63	22.17	37.50-62.50	46.00 ±1.13	5.67	12.33	50.00-100.00	70.50 ±2.27	11.34	16.09
May	187.50-337.50	263.50 ±7.58	37.93	14.40	37.50-50.00	42.75 ±0.86	4.30	10.06	62.50-112.50	78.50 ±2.45	12.25	15.60
June	175.00-325.00	263.00 ±8.45	42.25	16.06	37.50-56.25	42.75 ±0.93	4.66	10.91	62.50-100.00	74.00 ±2.16	10.78	14.56
July	225.00-375.00	288.00 ±8.31	41.53	14.42	37.50-43.75	41.75 ±0.60	2.98	7.13	62.50-100.00	78.00 ±1.81	9.04	11.59
August	250.00-375.00	309.00 ±8.02	40.10	12.98	37.50-43.75	40.25 ±0.63	3.17	7.87	62.50-125.00	85.00 ±2.98	14.88	17.50
September	125.00-312.50	275.00 ±7.97	39.84	14.49	37.50-50.00	40.25 ±0.73	3.64	9.05	50.00-87.50	73.50 ±1.95	9.76	13.28
October	162.50-400.00	255.00 ±10.78	53.89	21.13	37.50-50.00	41.25 ±0.81	4.03	9.78	50.00-100.00	76.50 ±2.43	12.14	15.87
November	175.00-437.50	280.50 ±12.23	61.14	21.80	37.50-50.00	42.25 ±0.83	4.15	9.81	50.00-112.50	79.50 ±3.14	15.68	19.72
December	187.50-375.00	276.00 ±9.18	45.92	16.64	37.50-50.00	40.50 ±0.73	3.66	9.04	50.00-87.50	75.50 ±2.22	11.11	14.72
	F = 4.26, p<0.01				F = 4.56, p<0.01				F = 15.49, p<0.01			

Table-14: Seasonal changes in the cell size of ray initials (as seen in tangential longitudinal sections) in the cambial zone in *Moringa oleifera*.

Months	Anticlinal Diameter (μm)				Periclinal Diameter (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	24.50-42.00	31.64±0.91	4.57	14.45	17.50-38.50	28.98±0.92	4.58	15.79
February	17.50-49.00	35.14±1.55	7.73	21.99	14.00-42.00	29.54±1.26	6.32	21.38
March	14.00-52.50	33.46±2.16	10.79	32.25	10.50-42.00	25.34±1.62	8.10	31.97
April	14.00-52.50	33.32±2.07	10.36	31.09	14.00-45.50	29.82±1.74	8.70	29.17
May	17.50-56.00	34.86±2.27	11.36	32.60	14.00-38.50	27.86±1.42	7.11	25.51
June	17.50-56.00	34.16±2.10	10.51	30.78	14.00-38.50	26.88±1.32	6.60	24.57
July	21.00-52.50	38.08±1.84	9.22	24.22	17.50-38.50	26.88±1.00	5.02	18.69
August	17.50-45.50	31.64±1.52	7.59	24.00	14.00-28.00	23.10±0.83	4.17	18.03
September	17.50-52.50	35.84±1.54	7.71	21.52	10.50-28.00	22.82±0.88	4.42	19.36
October	28.00-52.50	35.98±1.24	6.19	17.20	24.50-42.00	31.92±0.89	4.44	13.91
November	14.00-35.00	23.80±1.36	6.78	28.48	7.00-28.00	27.00±0.98	4.88	18.07
December	28.00-56.00	39.90±1.86	9.32	23.35	17.50-38.50	29.40±1.26	6.31	21.46
	F = 5.26, p<0.01				F = 10.24, p<0.01			

while the tall rays in February, March, September and November in *C. pentandra* (Fig.1).

In *F. glomerata*, the short rays occur more frequently in May and July, the medium size rays are found commonly occurring in October and November, while occurrence of tall rays are rare, they occur more frequently in April and August and totally absent in February, May, June and September.

In *M. oleifera* the tall rays are also rare and they occur only in March, June and October and totally absent in the rest of the months of a calendar year. Occurrence of short rays is very high and dominates from May to July and October to December, while the medium ones occur more frequently in January, February and August (Fig.1).

In *C. pentandra*, uniseriate and multiseriate rays occur more frequent than biseriate. The uniseriate rays occur more frequently in January, July, October and December, while biseriate dominate in February, April and June and multiseriate in March, May, August and September. The proportional distribution of the uniseriate, biseriate and multiseriate rays varies from 32-45%, 15-24% and 35-49% respectively during different months of a year (Fig.2).

In *F. glomerata* the multiseriate rays are dominant in number and constitute 50-70%. Following this, uniseriate rays are from 12-32%, while biseriate rays constitute 14-25% of totals rays of cambial zone. The uniseriate rays are comparatively more frequent in February, April and September while biseriate February, March, May, October and December and multiseriate in June, October and November (Fig. 2).

In *M. oleifera* the percentage of biseriate rays dominate over uniseriate and multiseriate rays throughout the year and

sometimes it goes up to 76% of the total count. The uniseriate rays vary from 20-36%, biseriate 52-76% and multiseriate 4-16% in round the year. The uniseriate rays are more frequent in April, May, August, September and December, while biseriate dominate in January, March, and October and multiseriate in July, August and November (Fig.2).

The amount of ray and fusiform initials undergo minor fluctuations in different months of a year. In *C. pentandra* the percentage area occupied by ray initial varies 37-49%, the maximum being in *February*, March, June, August and September while minimum occurring in May. In *F. glomerata* it is found to vary 34-42% maximum being in April, August and September, and minimum in May. In *M. oleifera* area occupied by ray initials varies from 28-37%, the maximum being in February, October, November and December and minimum in June (Fig.3).

Structure of secondary xylem:

In *C. pentandra*, wood is diffuse porous. Vessels are mostly medium sized, solitary or in groups, present in multiples of 2-12. Perforation simple, perforation plates slightly oblique to transverse, lateral walls having scalariform as well as overcrowded bordered pits. Parenchyma abundant, apotracheal to paratracheal and both but apotracheal is predominant, vasicentric. Rays typically 2-6 cells wide in transverse plane, homogenous (Plate-VII & VIII).

In *F. glomerata* wood is diffuse porous vessels are medium sized, solitary or groups present in 2-6, perforation exclusively simple, lateral walls of the vessels have over crowded, reduced border pits, perforation plates slightly oblique to transverse. Parenchyma typically paratracheal, usually aliform to confluent. Rays 2-10 cells wide, homogenous (Plate-IX & X).

In *M. oleifera* wood is diffuse porous. Vessels are solitary to multiples of 2-7, perforation simple, lateral walls of some vessels are pitted having overcrowded reduced bordered pits while a few have scalariform pits, intervascular pitting alternate having reduced borders. Parenchyma paratracheal, vasicentric or sometimes slightly aliform. Rays 1-3 cells wide, homogenous and composed of procumbent cells. Fibres moderately short (Plate-XI).

In tangential longitudinal sections, the ray parenchyma cells form rays of varying height and width. The height is found to vary from 1-71 cells in *C. pentandra*, 1-59 cells in *F. glomerata* and 1-23 cells in *M. oleifera*. Similarly, their width is noticed to vary from 1-9 cells, 1-20 cells and 1-3 cells respectively in the species investigated. Measurements of the

vessel elements have revealed that their length varies from 100.00 - 500.00 μm in *C. pentandra*, 62.50 - 525.00 μm in *F. glomerata* and 125.00 - 400.00 μm in *M. oleifera*. The radial and tangential diameters of the vessel elements are found to vary from 25.00/37.50-400.00/325.00 μm in *C. pentandra*, 37.50/37.50 -375.00/375.00 μm in *F. glomerata* and 25.00/50.00-412.50/337.50 μm in *M. oleifera* (Table 15). A comparison of length of vessel elements with their mother initials has revealed that they are almost equal in size to their mother initials in *C. pentandra* and *M. oleifera* while shorter in *F. glomerata* (Table 15).

The macerated fibre elements appear as elongated structure with mostly pointed ends. They appear to undergo apical elongation by means of apical intrusive growth to the extent of 2.58 to 5.01 times over the size of their mother initials namely the fusiform initials (Table-16). The intrusively grown elements posses newly formed apical parts made up of comparatively thin cellulose walls, enclosing bigger lumen, rich cytoplasmic contents. Such apices exhibit various types of structural manifestations, such as serrations, forking, bending, etc. They vary in length from 650.00-2625.00 μm in *C. pentandra*, 625.00 - 2437.50 μm in *F. glomerata* and 312.50 - 1275.00 μm in *M. oleifera* respectively (Table 16).

Analysis of transactions of adult wood samples of different species has revealed that the pores constitute about 28%, ray parenchyma 22%, sclerenchyma 18% and axial parenchyma 32% of the total transactional area of wood in *C. pentandra*. Similar estimation of *F. glomerata* has shown the occurrence of about 27% pores, 20% ray parenchyma, 26% sclerenchyma and 27% axial parenchyma and in *M. oleifera*

Table-15: Size of vessel elements and their length comparison with mother initials (fusiform initials) in the selected species (based on round year collections).

Species		Length of Fusiform Initials (μm)	Length of Vessel Elements (μm)	Diameter of Vessel Elements (μm)		Vessel Elements length/fusiform Initials length
				Radial	Tangential	
C. pentandra	Range	212.50-612.50	100.00-500.00	25.00-400.00	37.50-325.00	1.020
	Mean±S.E.	346.58 ±3.27	353.46±3.83	175.13±5.42	159.42±3.88	
	S.D.	56.62	66.29	93.92	67.12	
	C.V.%	16.69	19.02	52.01	40.36	
F. glomerata	Range	150.00-712.50	62.50-525.00	37.50-375.00	37.50-375.00	0.798
	Mean±S.E.	330.71 ±5.38	264.00±4.18	149.54±3.42	155.13±2.84	
	S.D.	93.25	72.35	59.24	49.14	
	C.V.%	28.62	27.13	38.90	30.79	
M. oleifera	Range	125.00-437.50	125.00-400.00	25.00-412.50	50.00-337.50	1.006
	Mean±S.E.	277.21 ±2.87	279.04±2.60	165.17±4.39	173.96±3.81	
	S.D.	49.71	45.00	76.04	65.96	
	C.V.%	18.23	16.13	46.04	37.92	

Table-16: Average length and width of xylem fibres and their length comparison with mother initials (fusiform initials) in the selected species (based on round the year collections).

Species		Length of Fusiform Initials (μm)	Length of Xylem Fibres (μm)	Width of Xylem Fibres (μm)	Extent of growth of Xylem Fibres
C. pentandra	Range	212.50-712.50	650.00-2625.00	12.50-56.25	5.013
	Mean±S.E.	346.58 ±3.27	1737.25±22.13	28.25±0.35	
	S.D.	56.62	383.32	6.01	
	C.V.%	16.69	22.48	21.29	
F. glomerata	Range	150.00-612.50	625.00-2437.50	12.50-37.50	4.151
	Mean±S.E.	330.71 ±5.38	1372.71±20.00	25.71±0.26	
	S.D.	93.25	346.44	4.49	
	C.V.%	28.62	25.20	17.46	
M. oleifera	Range	125.00-437.50	312.50-1275.00	31.25-75.00	2.582
	Mean±S.E.	277.21 ±2.87	715.79±10.63	51.96±0.47	
	S.D.	49.71	184.11	8.12	
	C.V.%	18.23	25.72	15.63	

30% pores, 29% ray parenchyma, 10%, sclerenchyma and 31% axial parenchyma (Fig.14).

Studies on tangential longitudinal sections of wood samples has revealed that the rays occupy 40% of the total longitudinal area in *C. pentandra,* 35% in *F. glomerata* and 33% in *M. oleifera* while the rest is occupied by other axial elements (Fig.13). The xylem rays have been classified into three groups based on their height viz. short (up to 300 μm), medium (301-600 μm) and tall (above 600 μm).

Developmental changes in the structure of secondary xylem:

Analysis of secondary xylem in the axis of various age group trees has revealed that the amount of secondary xylem increases with the increase in the age of tree axis and xylary elements also undergo significant dimensional variations with the advancing age of the plant axis. The average length of vessel elements shows an increase with the increasing girth of the axis in *C. pentandra*. In *F. glomerata* and *M. oleifera*, average length of vessel elements initially increase with the age and after experiencing a slight decline again there is a gain in length with the advancing age (Tables 17-19). Observations on radial and tangential diameter of vessel elements have revealed that in *C. pentandra* and *F.* glomerata radial and tangential diameter first undergo expansion with increasing age of the axis which is followed by a declining tendency near the basal regions. In *M. oleifera* radial diameter shows an initial increase and appears to be followed by constancy while tangential diameter shows an increasing tendency from top towards the base (Tables 17-19).

The xylem fibres also exhibit some changes in their dimensions with the growing age of the tree axis. The average length of fibres has been found to vary from 1134.00 - 1828.00 μm in *C. pentandra*, 1031.50-1416.00 μm in *F. glomerata*, 571.00 - 736.00 μm in *M. oleifera* and their average width varies from 25.00 - 28.25 μm, 23.75 - 26.50 μm and 32.50 - 55.75μm respectively (Tables 20-22).

Observations regarding the percentage area occupied in transverse plain by the different components of xylem in the wood samples collected from the axis of varying diameters

Table-17: Changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Ceiba pentandra*.

Circumference of the axis in Cm.	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	100.00-400.00	270.00 ±18.01	90.08	33.36	25.00-237.50	118.00 ±14.84	74.22	62.90	25.00-225.00	117.50 ±10.75	53.76	45.76
55	175.00-437.50	280.00 ±13.95	69.77	24.92	37.50-300.00	170.00 ±14.60	73.02	42.95	87.50-287.50	130.00 ±11.01	55.07	42.36
80	225.00-500.00	355.00 ±11.88	59.40	16.73	125.00-350.00	206.50 ±12.06	60.29	29.19	125.00-275.00	152.00 ±10.38	51.90	34.15
105	187.50-500.00	363.00 ±13.82	69.10	19.05	37.50-262.50	165.50 ±15.21	76.06	45.96	87.50-250.00	160.50 ±11.38	56.90	35.45
150	250.00-437.50	369.00 ±8.99	44.94	12.18	37.50-312.50	154.50 ±14.75	73.76	47.74	50.00-250.00	145.50 ±10.48	52.40	36.01
	F=2.64, $p<0.05$				F=6.27, $p<0.01$				F=7.18, $p<0.01$			

Table-18: Changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Ficus glomerata*.

Circumference of the axis in Cm.	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	137.50-375.00	251.50 ±11.97	59.87	23.81	25.00-175.00	88.50 ±8.23	41.13	46.47	37.50-187.50	99.50 ±8.52	42.62	42.83
55	100.00-350.00	298.00 ±11.46	57.32	19.23	50.00-212.50	135.00 ±8.60	43.00	31.85	87.50-162.50	136.50 ±3.81	19.07	13.97
80	175.00-375.00	273.50 ±8.27	41.35	15.12	50.00-350.00	190.00 ±15.38	76.89	40.47	100.00-287.50	160.00 ±11.30	56.48	35.30
105	200.00-437.50	303.50 ±12.09	60.44	19.91	37.50-262.50	180.00 ±12.24	61.19	34.00	112.50-250.00	176.00 ±6.73	33.64	19.11
150	225.00-500.00	305.00 ±14.42	72.08	23.63	62.50-275.00	172.00 ±11.75	58.77	34.17	62.50-225.00	139.00 ±7.72	38.58	27.76
	F = 4.28, p<0.01				F = 11.81, p<0.01				F = 24.57, p <0.01			

Table-19: Changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Moringa oleifera*.

Circumference of the axis in Cm.	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	150.00-375.00	264.50 ±8.62	43.10	16.30	37.50-237.50	134.50 ±11.67	58.33	43.37	50.00-200.00	128.50 ±9.26	46.28	36.02
55	212.50-375.00	275.00 ±7.43	37.15	13.51	25.00-250.00	141.00 ±12.11	60.54	42.94	62.50-262.50	161.50 ±12.70	63.52	39.33
80	250.00-362.50	299.00 ±7.25	36.25	12.12	37.50-287.50	149.50 ±15.93	79.67	53.29	37.50-275.00	165.00 ±13.53	67.63	40.99
105	212.50-375.00	274.50 ±8.21	41.06	14.96	25.00-287.50	150.00 ±16.54	82.68	55.12	62.50-312.50	166.00 ±13.74	68.70	41.39
150	225.00-375.00	282.50 ±8.98	44.92	15.90	50.00-287.50	150.50 ±13.04	65.20	43.32	62.50-325.00	170.00 ±12.81	64.03	37.67
	F = 2.49, $p<0.05$				F = 0.26, p is non-significant				F = 1.39, p is non-significant			

Table-20: Changes in the dimension of xylem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Ceiba pentandra*.

Circumference of the axis in Cm.	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	800.00-2250.00	1134.00±82.37	411.86	36.32	18.75-31.25	25.75±0.66	3.29	12.77
55	875.00-2437.50	1480.00±79.05	395.25	26.71	12.50-31.25	25.00±0.72	3.61	14.43
80	875.00-2312.50	1610.00±80.28	401.38	24.93	18.75-37.50	26.50±0.83	4.15	15.64
105	1187.50-2437.50	1760.50±61.12	305.60	17.36	25.00-37.50	26.75±0.77	3.84	14.34
150	1150.00-2500.00	1828.00±71.06	355.30	19.44	25.00-37.50	28.25±0.96	4.81	17.04
F=3.87, $p<0.01$					F=2.35, $p<0.05$			

Table-21: Changes in the dimension of xylem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Ficus glomerata*.

Circumference of the axis in Cm.	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	675.00-1400.00	1031.50±38.92	194.59	18.86	18.75-31.25	24.25±0.55	2.75	11.33
55	750.00-1725.00	1276.50±42.48	212.39	16.64	12.50-25.00	23.75±0.63	3.13	13.16
80	812.50-1775.00	1251.50±57.98	289.92	23.17	18.75-37.50	26.50±0.75	3.73	14.09
105	775.00-2200.00	1399.00±59.66	298.28	21.32	18.75-37.50	26.25±0.72	3.61	13.75
150	737.50-2225.00	1416.00±77.95	389.75	27.52	18.75-37.50	25.75±0.83	4.16	16.16
F=7.29, $p<0.01$					F=3.07, $p<0.01$			

Table-22: Changes in the dimension of xylem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Moringa oleifera*.

Circumference of the axis in Cm.	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	275.00-800.00	571.00±31.97	159.86	28.00	18.75-50.00	32.50±1.91	9.55	29.38
55	350.00-900.00	650.00±29.98	149.91	23.06	31.25-56.25	46.25±1.35	6.75	14.60
80	475.00-975.00	711.00±28.14	140.70	19.79	37.50-62.50	49.50±1.35	6.75	13.64
105	400.00-1100.00	678.00±34.48	172.39	25.43	37.50-62.50	50.00±1.30	6.49	12.96
150	462.50-1075.00	736.00±34.19	170.95	23.23	43.75-75.00	55.75±2.01	10.03	18.00
F = 5.01, p<0.01					F = 29.08, p<0.01			

have revealed that they differ to a certain extent in different samples. The vessel area is found to vary 18-27% in *C. pentandra*, 21-30% in *F. glomerata* and 25-33% in *M. oleifera* vessel area increases with increase in the girth of the axis in all the species investigated (Fig. 7). Similarly, the amount of other components has been found to vary in different samples. The ray parenchyma is found varying from 24 - 30% in *C. pentandra*, 17-27% in *F. glomerata* and 31-33% in *M. oleifera*. The sclerenchyma varying from 18-25, 24-29% and 10-15% respectively. The axial parenchyma varies from 29-32%, 21-38% and 26-27% in three species investigated respectively. In all three species investigated ray parenchyma shows inconsistent behaviour with respect to the age of the axis. Sclerenchyma and axial parenchyma do not exhibit any specific trend of variation with the increase in age (Fig.7).

The tall and uniseriate rays vary from 36-45% to 30-20% in *C. pentandra* and in *F. glomerata* tall and uniseriate rays vary from 5-19% to 4-2%. While in *M. oleifera* tall and uniseriate rays vary from 1-10% to 31-21% from younger to older axis (Figs. 8 & 9).

In tangential longitudinal section the percentage area occupied by wood ray varies from 33-43% in *C. pentandra*, 29-35% in *F. glomerata* and 27-38% *M. oleifera* (Fig.10).

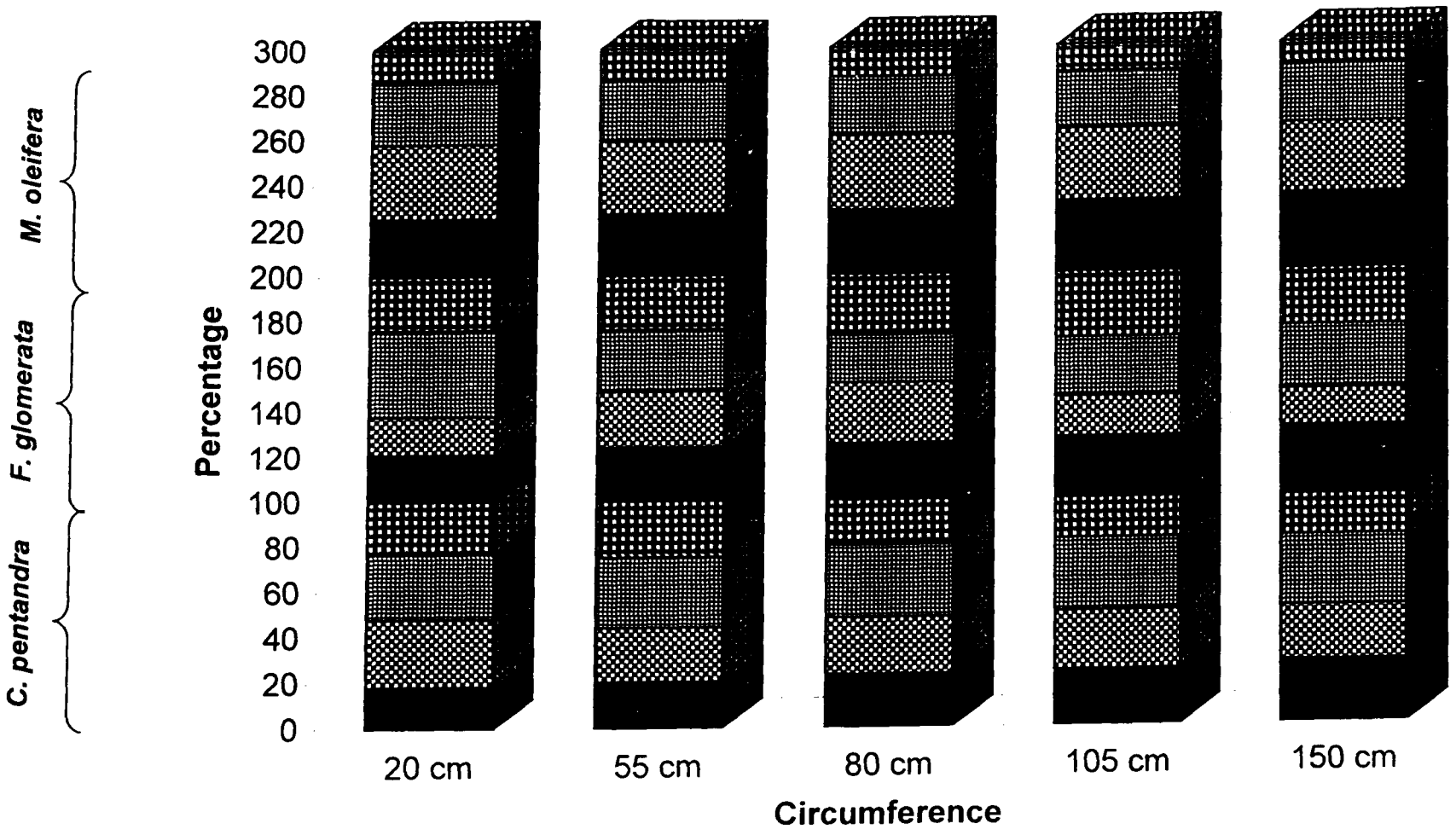


Figure-7: Percent transectional area xylem components.

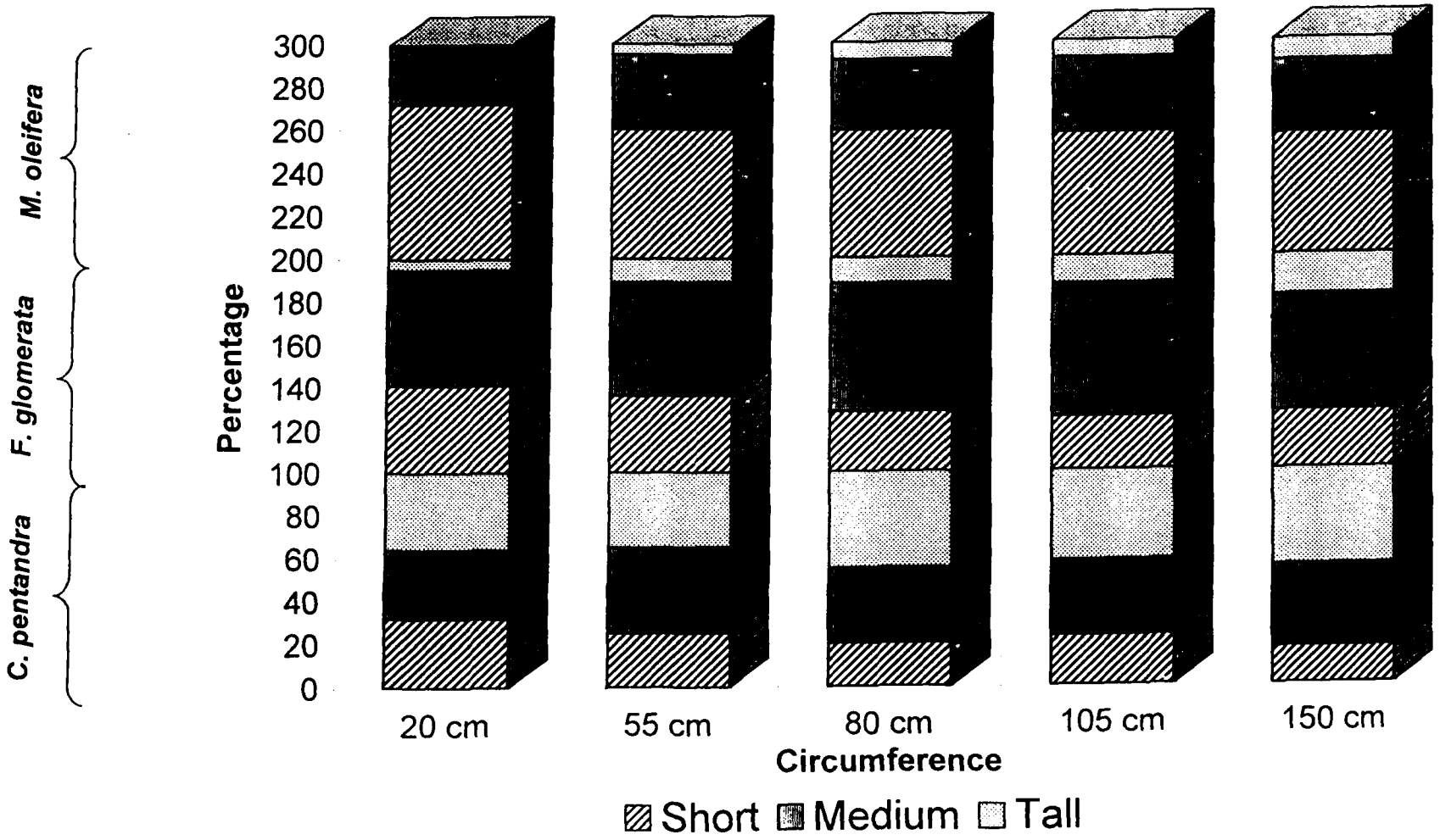


Figure-8: Percent xylem rays.

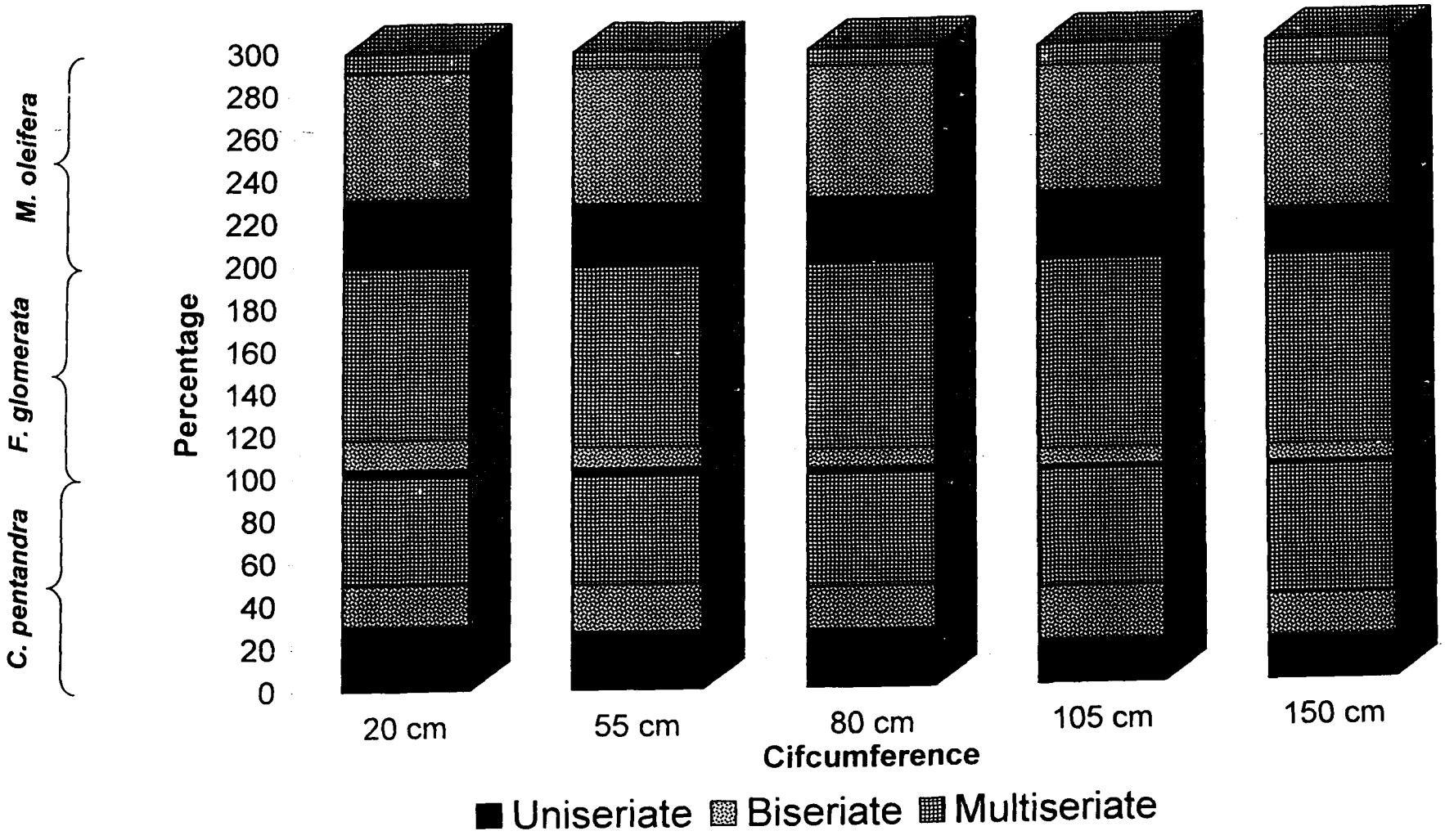


Figure-9: Percent xylem rays.

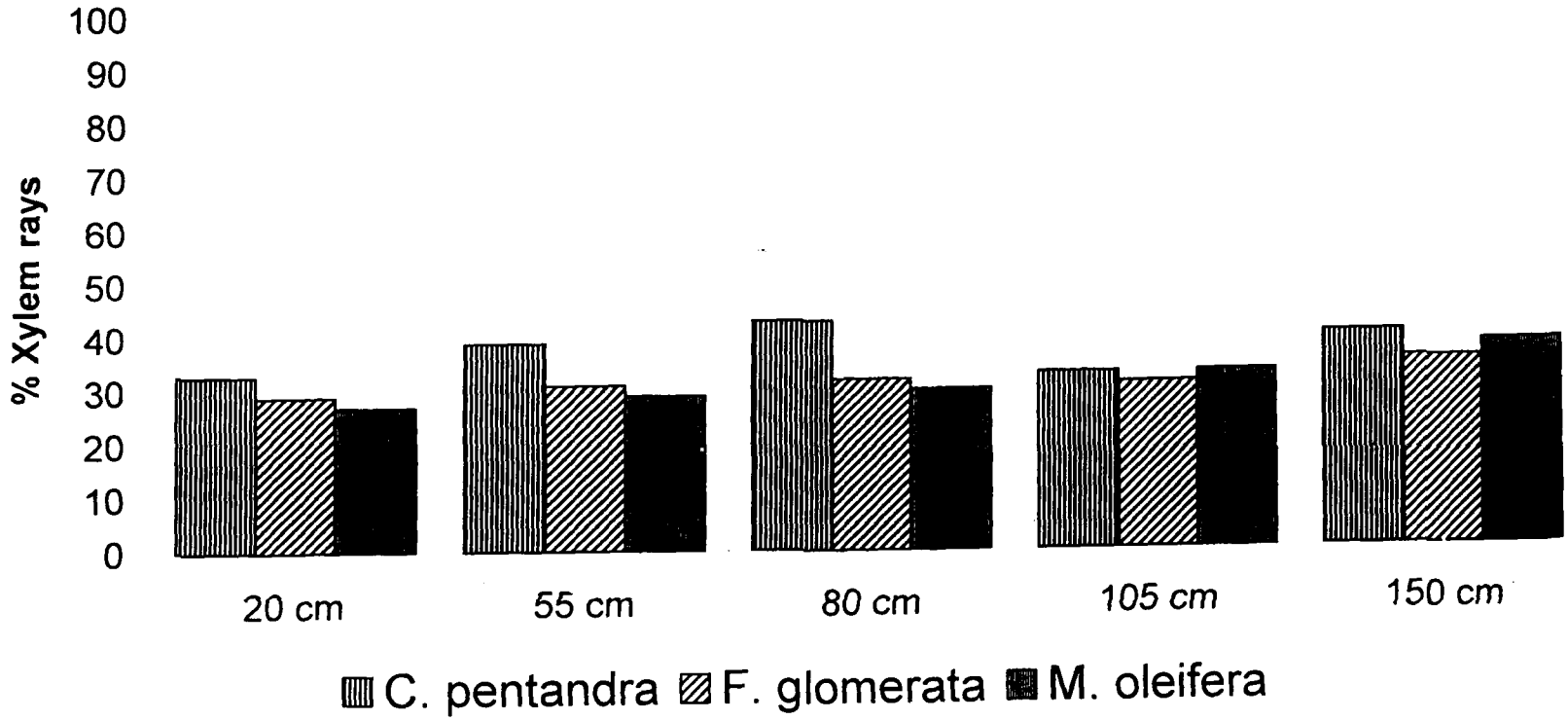


Figure-10: Percent tangential area (xylem rays).

Seasonal changes in the structure of secondary xylem:

The immediate inner derivatives of cambium were analysed every month in order to find out the variations in the size of the vessel elements and xylem fibres produced in different seasons.

As regard the length of the vessel elements it has been found that the length of vessel element varies from 100.00 - 500.00 μm in the *C. pentandra*, 62.50-525.00 μm in *F. glomerata* and 125.00-400.00 μm in *M. oleifera* in different seasons. The minimum average size of vessel element i.e. 308.00 μm is noticed in April and maximum average size i.e. 375.50 μm in January in *C. pentandra*. Comparatively short elements occur more frequently in March, April and June, while the taller ones in January, February, July, September and November. Similarly, in *F. glomerata* their average length has been found ranging from 226.00 to 280.00 μm with shorter elements occurring in November, while the taller ones in January, March, May, June and August. In *M. oleifera*, the average vessel length varies from 231.50 to 303.00 μm with short ones occurring in April and taller elements in May, June, August and September (Tables 23-25). Measurements of the radial and tangential diameter of vessels in *C. pentandra* have revealed that the average size of the radial diameter ranges from 147.50 - 215.00 μm and tangential diameter from 134.50 - 193.50 μm in different months. In *F. glomerata* mean of the radial and tangential diameter is found to vary from 125.00 - 185.50 μm and 129.00–196.00 μm and in *M. oleifera* it varies from 148.00–189.50 μm and 149.50–196.00 μm respectively (Tables 23-25).

Table-23: Seasonal changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Ceiba pentandra*.

Months	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	250.00-450.00	375.50 ±11.05	55.26	14.72	50.00-375.00	180.00± 16.17	80.84	44.91	100.00-325.00	153.00 ±10.30	51.50	33.66
February	250.00-437.50	369.00 ±8.99	44.94	12.18	37.50-312.50	154.00 ±14.75	73.76	47.74	50.00-250.00	145.50 ±10.48	52.40	36.01
March	225.00-450.00	337.00 ±11.10	55.49	16.47	37.50-350.00	193.50 ±19.66	98.30	50.80	75.00-275.00	172.00 ±13.02	65.08	37.84
April	100.00-400.00	308.00 ±19.16	95.81	31.11	50.00-300.00	162.00 ±15.44	77.18	47.64	37.50-212.50	137.50 ±7.77	38.86	28.26
May	225.00-437.50	349.00 ±10.65	53.27	15.26	25.00-325.00	150.00 ±20.03	100.13	66.75	50.00-250.00	148.00 ±11.29	56.44	38.14
June	225.00-425.00	339.50 ±13.16	65.82	19.39	37.50-400.00	215.00 ±22.26	111.28	51.76	75.00-287.50	193.50 ±14.86	74.31	38.40
July	250.00-500.00	368.50 ±12.91	64.56	17.52	37.50-400.00	154.50 ±19.84	99.21	64.21	50.00-325.00	141.50 ±17.58	87.92	62.14
August	150.00-412.50	349.00 ±11.41	57.05	16.35	50.00-362.50	206.00 ±19.43	97.17	47.17	62.50-250.00	182.00 ±10.46	52.30	28.74
September	325.00-437.50	367.50 ±5.64	28.18	7.67	37.50-312.50	195.50 ±18.65	93.25	47.70	50.00-325.00	182.00 ±15.21	76.04	41.79
October	250.00-412.00	356.50 ±8.10	40.52	11.37	37.50-375.00	188.50 ±18.82	94.09	49.92	62.50-262.50	171.00 ±11.13	55.64	32.54
November	312.00-437.00	368.50 ±6.04	30.22	8.20	37.50-287.50	147.50± 16.43	82.13	55.68	50.00-275.00	152.50 ±14.11	70.53	46.25
December	150.00-475.00	353.50 ±16.05	80.24	22.70	50.00-262.50	154.50 ±14.07	70.33	45.52	62.50-212.00	134.50 ±9.11	45.54	33.86
	F=8.18, p<0.01				F=3.02, p<0.01				F=5.60, p<0.01			

Table-24: Seasonal changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Ficus glomerata*.

Months	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	100.00-412.50	274.50 ±14.33	71.67	26.11	100.00-325.00	145.00 ±11.61	58.06	40.04	62.50-375.00	160.00 ±12.15	60.74	37.96
February	100.00-350.00	261.00 ±11.46	57.32	21.96	37.50-262.50	128.50 ±12.24	61.19	47.61	62.50-225.00	139.00 ±7.72	38.58	27.76
March	62.50-525.00	270.50 ±19.62	98.09	36.26	75.00-250.00	161.50 ±9.18	45.92	28.43	112.50-287.50	196.00 ±8.40	42.04	21.45
April	125.00-475.00	268.00 ±14.56	72.80	27.17	87.50-250.00	163.00 ±8.76	43.82	26.88	112.50-237.50	172.00 ±6.93	34.66	20.15
May	187.50-462.50	280.00 ±12.41	62.03	22.15	37.50-262.50	135.00 ±10.05	50.26	37.23	62.50-200.00	134.50 ±8.14	40.71	30.27
June	175.00-400.00	271.00 ±11.94	59.70	22.03	50.00-187.50	125.00 ±8.32	41.61	33.29	87.50-225.00	149.50 ±6.27	31.35	20.97
July	125.00-450.00	269.50 ±14.63	73.16	27.14	75.00-312.50	185.50 ±12.28	61.42	33.11	50.00-262.50	160.50 ±9.73	48.64	30.30
August	150.00-400.00	270.50 ±13.69	68.45	25.31	62.50-250.00	151.50 ±12.02	60.09	39.66	87.50-225.00	152.50 ±7.32	36.62	24.01
September	112.50-375.00	255.00 ±15.21	76.03	29.82	37.50-375.00	178.50 ±13.78	68.89	38.60	75.00-312.50	186.00 ±11.87	59.33	31.90
October	150.00-375.00	254.00 ±13.88	69.38	27.32	50.00-250.00	139.00 ±11.55	57.77	41.56	75.00-200.00	144.50 ±6.65	33.28	23.03
November	100.00-400.00	226.00± 14.95	74.73	33.07	50.00-250.00	139.00 ±8.94	44.68	32.14	75.00-187.50	138.00 ±6.02	30.08	21.80
December	162.00-387.50	268.00 ±12.50	62.51	23.32	50.00-187.00	143.00 ±8.70	43.52	30.44	37.50-187.50	129.00 ±8.38	41.88	32.47
	F = 1.86, p <0.05				F = 6.75, p < 0.01				F = 9.98, p<0.01			

Table-25: Seasonal changes in the length of vessel elements (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Moringa oleifera*.

Months	Length of Vessel Elements (μm)				Diameter of Vessel Elements (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	187.50-375.00	286.00 ±7.98	39.91	13.95	37.50-337.50	171.50 ±15.49	77.44	45.15	62.50-337.50	189.00 ±15.47	77.34	40.92
February	225.00-375.00	282.50 ±8.98	44.92	15.90	50.00-287.50	150.50 ±13.04	65.20	43.32	62.50-325.00	154.50 ±12.81	64.03	41.44
March	175.00-350.00	258.50 ±7.70	38.48	14.89	25.00-337.50	149.50 ±17.45	87.24	58.35	62.50-337.50	169.50 ±15.83	79.15	46.70
April	125.00-312.50	231.50 ±11.44	57.18	24.70	25.00-287.50	159.50 ±14.51	72.55	45.49	100.00-300.00	174.00 ±11.57	57.84	33.24
May	150.00-375.00	296.50 ±9.48	47.40	15.99	25.00-412.50	189.50 ±22.94	114.72	60.54	87.50-325.00	196.00 ±16.08	80.42	41.03
June	212.50-400.00	303.00 ±9.02	45.11	14.89	50.00-287.50	161.00 ±14.76	73.80	45.84	50.00-275.00	175.50 ±12.43	62.13	35.40
July	225.00-375.00	282.50 ±7.53	37.67	13.34	62.50-262.50	161.00 ±12.67	63.36	39.35	62.50-225.00	158.50 ±9.15	45.75	28.86
August	175.00-400.00	292.00 ±9.41	47.03	16.11	50.00-312.50	148.00 ±14.30	71.51	48.31	50.00-325.00	149.50 ±14.10	70.48	47.14
September	237.50-375.00	292.50 ±7.36	36.80	12.58	62.50-287.50	186.00 ±12.46	62.32	33.51	87.50-300.00	194.00 ±9.44	47.20	24.33
October	187.50-375.00	274.00 ±7.46	37.31	13.62	25.00-312.50	163.00 ±14.02	70.11	43.01	50.00-312.50	170.50 ±13.99	69.96	41.03
November	212.50-375.00	280.50 ±6.29	31.47	11.22	62.50-337.50	181.00 ±13.37	66.84	36.93	87.50-325.00	190.50 ±11.86	59.32	31.14
December	212.50-337.50	269.00 ±6.13	30.64	11.39	50.00-337.50	161.50 ±15.05	75.25	46.60	62.50-312.50	166.00 ±12.11	60.54	36.47
F = 5.35, p<0.01					F = 0.84, p is non-significant				F = 1.43, p is non-significant			

The macerated fibre elements were measured to determine their dimensional variation in different months of a calendar year. Their average length is recorded to vary from 1570.00–1951.50 μm in *C. pentandra* with the minimum average length occurring in March and maximum in November, from 1199.50–1559.50 μm in *F. glomerata* with larger elements occurring in August and smaller ones in May and from 613.00–964.00 μm in *M. oleifera* with larger and smaller elements occurring in July and April respectively (Tables 26-28). Studies on the width of the fibres have shown that their average size varies from 25.00 - 30.50 μm in *C. pentandra,* from 24.75 - 28.00 μm in *F. glomerata* and from 44.75-55.75 μm in *M. oleifera* (Tables 26-28).

The wood rays as their mother initials in the cambium, differ in height and width to a considerable extent in different months. Analysis of the immediate xylem derivatives in fortnightly collections has shown that the tall rays occur more frequently in January, February, April, May and November and vary from 36-53% during a calendar year in *C. pentandra*. In *F. glomerata* they constitute about 5-17%, taller ones occurring more in January, May, October and November, while in *M. oleifera* percentage of tall rays varies 3-13%, their occurrence being more in January to March and October and November. The tall rays are found dominating over short and medium in *C. pentandra*, but in *F. glomerata* medium rays are found dominating over short and tall rays while in *M. oleifera* short rays are noticed to dominate over the medium and tall rays (Fig.11). Relative frequency of small, medium and tall rays appears to be slightly influenced by the seasonal fluctuations in all the three investigated species but without any specific trend (Fig.11).

Table-26: Seasonal changes in the dimension of xylem fibres (as seen in macerated samples) in the *Ceiba pentandra*.

Months	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	650.00-2375.00	1724.00 ±91.78	458.90	26.62	12.50-37.50	28.75 ±1.14	5.71	19.85
February	1150.00-2500.00	1828.00 ±71.06	355.30	19.44	25.00-37.50	28.25 ±0.96	4.81	17.04
March	750.00-1937.50	1570.00 ±77.90	389.48	24.81	12.50-56.25	27.50 ±1.94	9.72	35.33
April	687.50-2050.00	1640.50 ±66.55	332.75	20.28	25.00-50.00	30.50 ±1.32	6.58	21.59
May	1125.00-2125.00	1703.50 ±61.19	305.96	17.96	25.00-37.50	28.50 ±0.81	4.07	14.27
June	650.00-1850.00	1600.00 ±54.48	272.41	17.03	12.50-31.25	25.00 ±0.95	4.77	19.09
July	1100.00-1937.00	1670.00 ±51.30	256.48	15.36	25.00-37.50	28.25 ±0.82	4.08	14.45
August	812.50-2562.50	1872.00 ±82.30	411.49	21.98	12.50-37.50	28.50 ±1.15	5.73	20.10
September	650.00-2437.50	1907.50 ±79.02	395.12	20.71	12.50-37.50	29.00 ±1.13	5.67	19.56
October	725.00-2125.00	1658.50 ±64.83	324.17	19.55	18.75-37.50	27.75 ±1.03	5.13	18.48
November	1375.00-2625.00	1951.50 ±69.21	346.08	17.73	18.75-50.00	29.75 ±1.70	8.52	28.63
December	1062.00-2562.50	1721.50 ±72.34	361.70	21.01	25.00-37.50	27.25 ±0.80	3.99	14.63
F = 5.47, p<0.01					F = 1.31, p is not significant			

Table-27: Seasonal changes in the dimension of xylem fibres (as seen in macerated samples) in the *Ficus glomerata*.

Months	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	737.50-2312.50	1327.00±68.38	341.88	25.76	12.50-31.25	24.75±0.99	4.93	19.94
February	737.50-2225.00	1416.50±77.79	388.97	27.46	18.75-37.50	25.75±0.83	4.16	16.16
March	625.00-2275.00	1310.00±75.48	377.41	28.81	12.50-37.50	25.25±0.99	4.93	19.54
April	775.00-2150.00	1332.50±66.86	334.32	25.09	18.75-37.50	26.50±0.90	4.52	17.06
May	625.00-2437.50	1199.50±76.30	381.51	31.81	12.50-37.50	24.75±1.17	5.84	23.60
June	625.00-2175.00	1233.00±64.80	324.01	26.28	18.75-37.50	25.00±0.81	4.03	16.14
July	950.00-2312.50	1504.00±68.12	340.61	22.65	12.50-37.50	26.00±1.06	5.32	20.44
August	1000.00-2375.00	1559.50±68.26	341.28	21.88	18.75-37.50	25.00±0.81	4.03	16.14
September	1000.00-2350.00	1396.50±57.28	286.40	20.51	18.75-37.50	27.00±0.86	4.32	15.98
October	975.00-2125.00	1424.00±46.11	230.54	16.19	18.75-31.25	25.75±0.55	2.75	10.67
November	925.00-2262.00	1439.00±68.48	342.40	23.79	18.75-37.50	28.00±0.89	4.46	15.94
December	625.00-1850.00	1331.00±67.25	336.22	25.26	18.75-31.25	24.75±0.67	3.37	13.60
F =2.40, p<0.01					F = 1.33, p is non-significant			

Table-28: Seasonal changes in the dimension of xylem fibres (as seen in macerated samples) in the *Moringa oleifera*.

Months	Length of Xylem Fibers (μm)				Width of Xylem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	475.00-1025.00	717.50±27.23	136.17	18.98	43.75-75.00	55.75±1.57	7.85	14.08
February	462.50-1075.00	736.00±34.19	170.95	23.23	43.75-75.00	55.75±2.01	10.03	18.00
March	375.00-1125.00	712.50±35.33	176.63	24.79	37.50-62.50	52.50±1.40	6.99	13.31
April	337.50-812.50	613.00±24.30	121.49	19.82	37.50-62.50	52.25±1.69	8.44	16.15
May	425.00-1000.00	650.00±32.41	162.06	24.93	37.50-62.50	51.25±1.40	6.99	13.63
June	312.50-1050.00	669.50±35.10	175.52	26.22	43.75-54.00	54.00±1.57	7.84	14.52
July	487.50-1275.00	964.00±44.24	221.19	22.94	43.75-75.00	55.75±1.57	7.85	14.08
August	500.00-1087.50	734.50±29.17	145.83	19.85	43.75-75.00	53.50±1.58	7.88	14.73
September	525.00-1225.00	794.50±33.78	168.91	21.26	31.25-56.25	44.75±1.47	7.37	16.47
October	475.00-1150.00	695.50±35.43	177.14	25.47	43.75-62.50	50.00±1.08	5.41	10.83
November	337.50-900.00	641.00±30.46	152.31	23.76	37.50-62.50	47.75±1.30	6.48	13.56
December	400.00-975.00	661.50±28.07	140.35	21.22	37.50-62.50	50.25±1.37	6.87	13.66
		F = 7.97, p<0.01				F = 5.03, p<0.01		

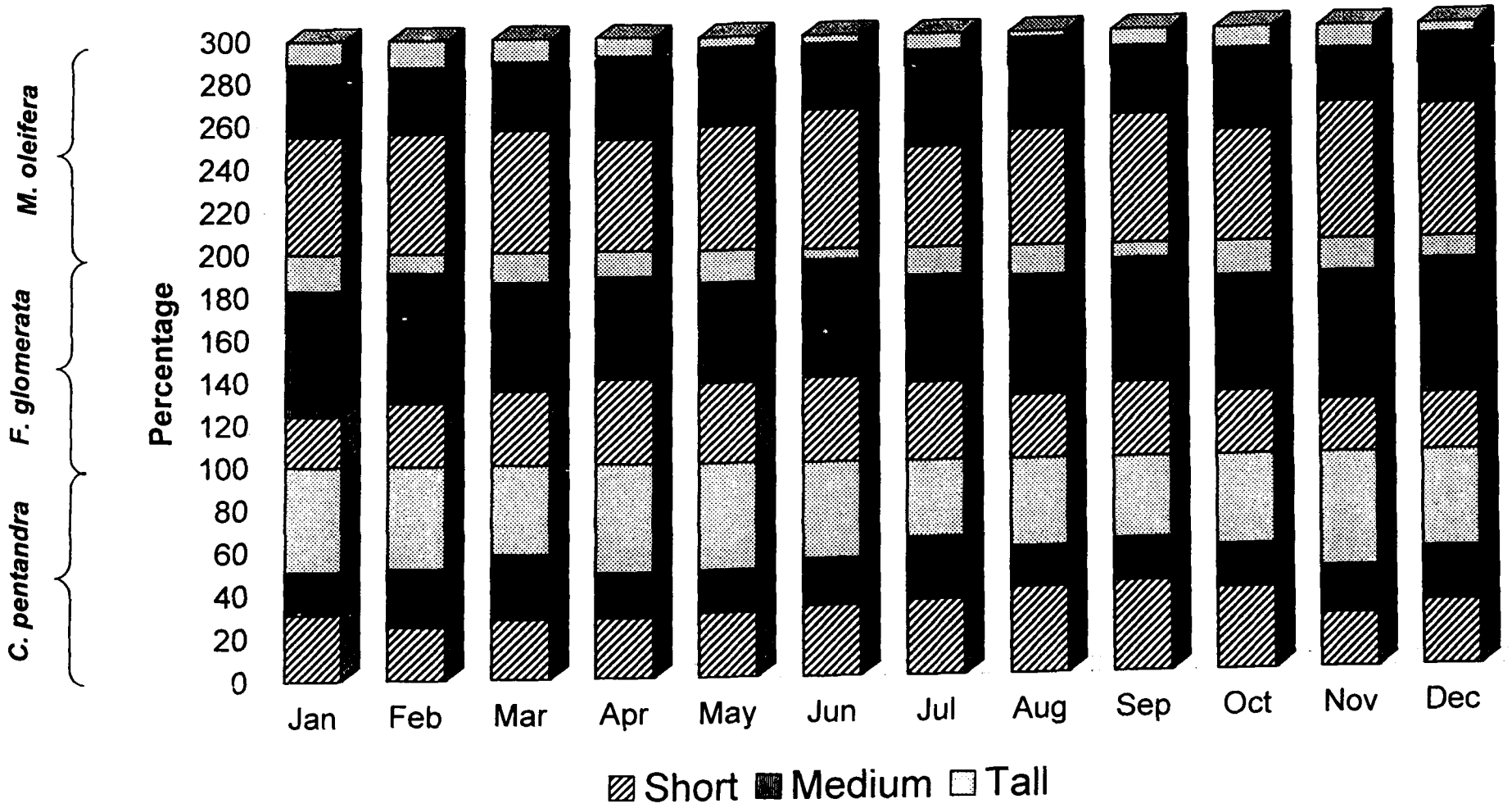


Figure-11: Percent xylem rays.

Observations and analysis of data collected on the width of rays has revealed that in *C. pentandra* and *F. glomerata*, the multiseriate rays are found dominating over uniseriate and biseriate rays in all seasons. The multiseriate rays constitute 47-59%, 72-97%, the biseriate 15-29%, 2-21% and uniseriate from 20-30%, 1-12% in different months of calendar year respectively. In *M. oleifera*, the biseriate rays dominate in all seasons and constitute 42-70%, the uniseriate 21-50% and multiseriate 3-16% during year of investigation (Fig.12).

Estimation of area occupied by ray parenchyma cells in tangential plane has shown that it varies from 33-46%, in *C. pentandra*, 31-36% in *F. glomerata* and 30-38% in *M. oleifera* in different months of a year, with an average of about 40%, 34% and 33% in respective species. Thus the area occupied by ray parenchyma cells in tangential planes is found to be higher in *C. pentandra* and almost equal in *F.* glomerata and *M. oleifera* that is varying 33-40% (Fig.13).

Analysis of transactions of the monthly collection of adult wood of the selected species has shown that area occupied by the different components of the xylem shows minor fluctuations. The pore area is found varying from 23-37%, ray parenchyma 20-26%, sclerenchyma 13-27% and axial parenchyma 27-37% in *C. pentandra*. In *F. glomerata*, the area occupied by the different xylem components it has been found that the vessels occupy from 24-30%, ray parenchyma 16-27%, sclerenchyma 20-32% and axial parenchyma 25-31% of total transactional area. While in *M. oleifera* the vessel occupy 27-35%, ray parenchyma 21-34%, sclerenchyma 9-14% and axial parenchyma 26-35% (Fig.14). In all the three species investigated, relative area occupied by different xylem

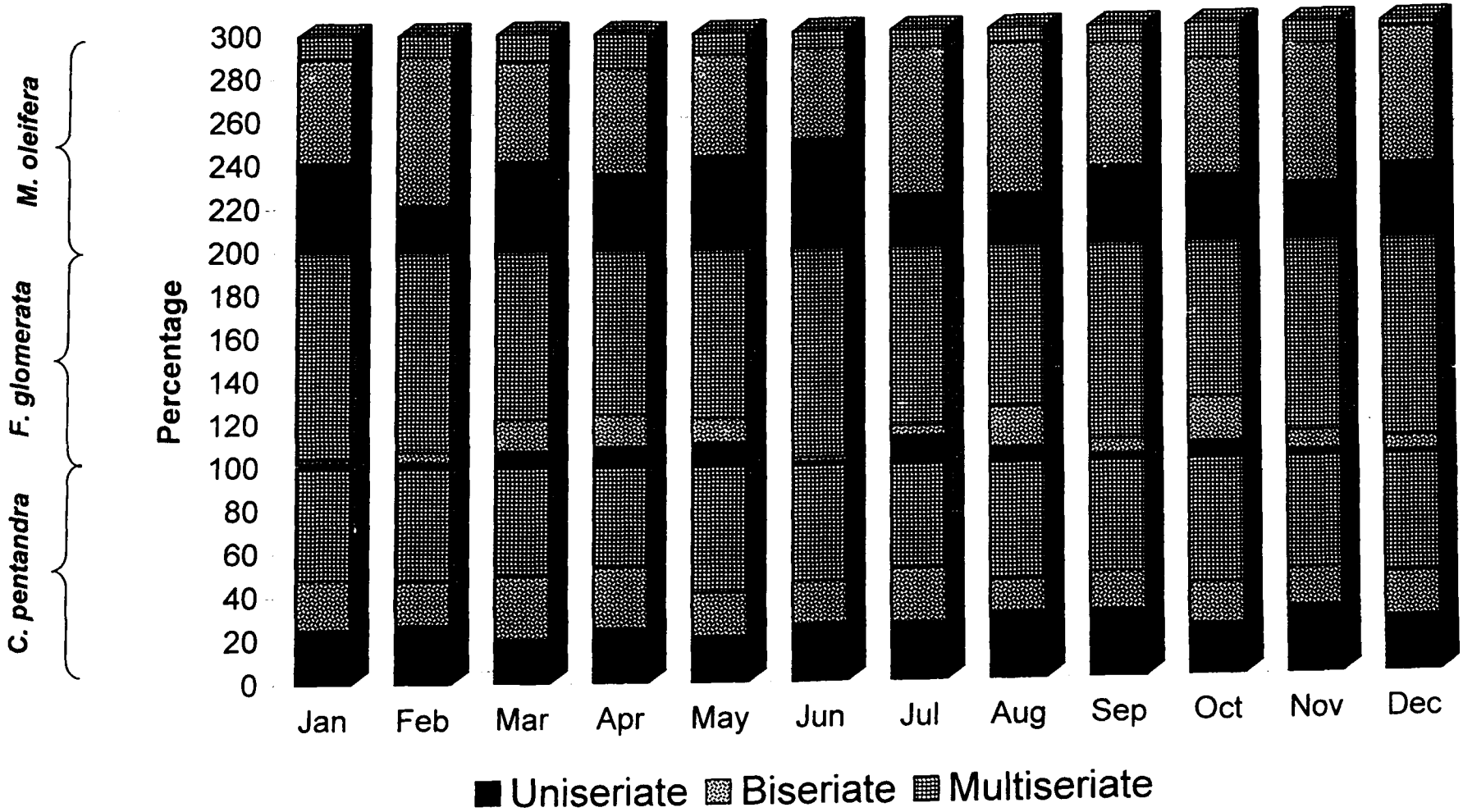


Figure-12: Percent xyleml rays.

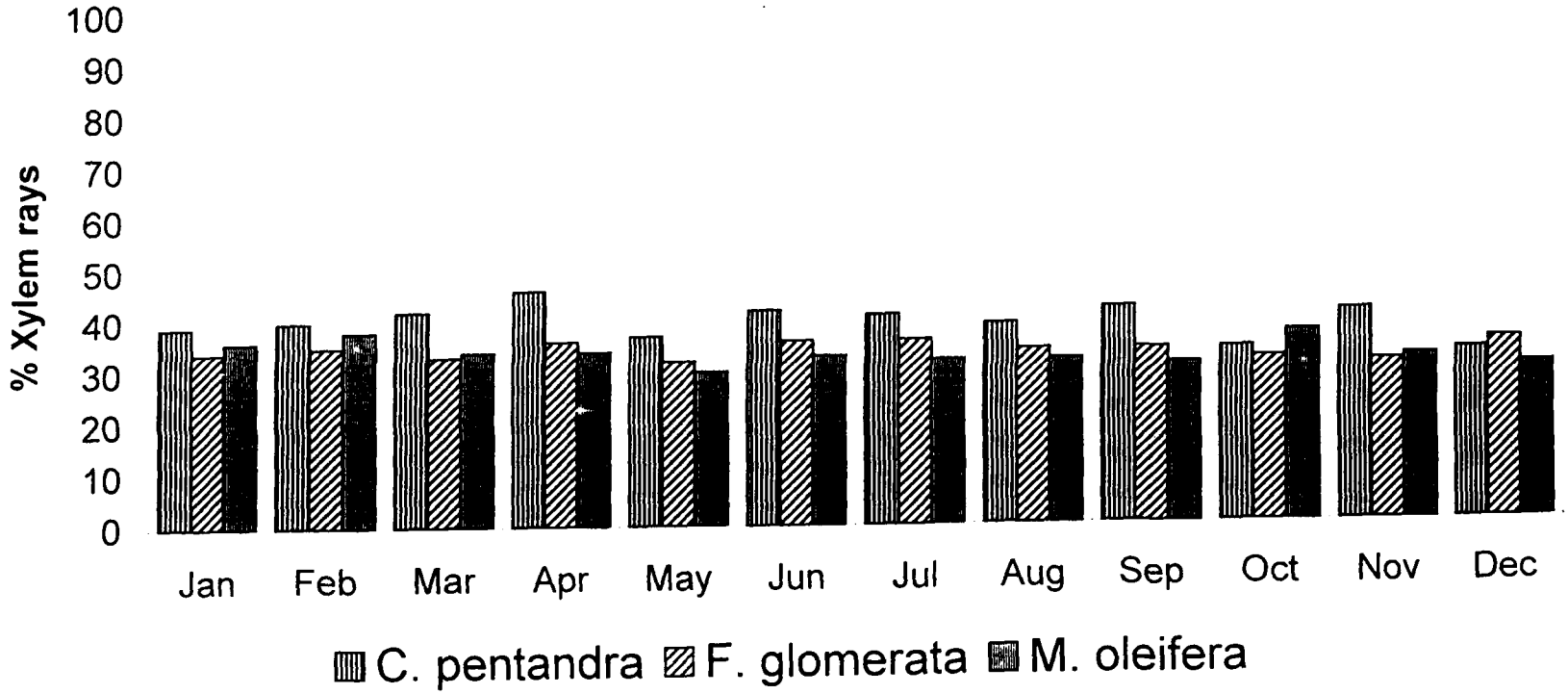


Figure-13: Percent tangential area (xylem rays).

components do not show any specific trend of variations with respect to the different seasons and appear not to be directly influenced by cambial behaviour. A comparison of the vessel area of the three selected species has revealed that it varies from 27% to 30% in the presently investigated species (Fig. 14).

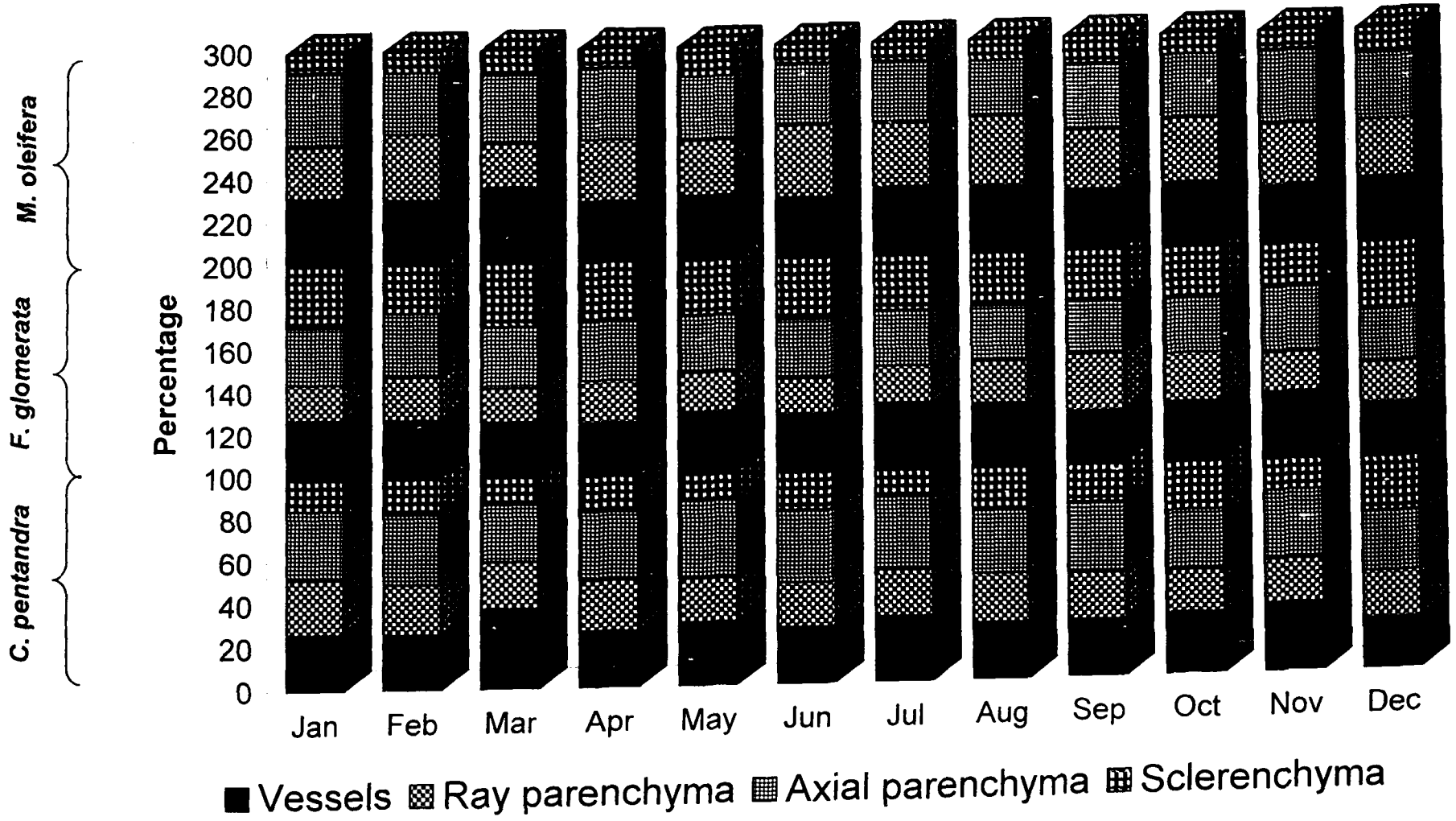


Figure-14: Percent transectional area xylem components.

Structure of secondary phloem:

The term bark is used to include all tissues lying outside the vascular cambium of the shoot axis, constitute the different phloem components, the pericycle, the endodermis, the cortex and the epidermis, while in the older region, secondary phloem and periderm form the bark. Externally, the bark of the older region of the plant axis of *C. pentandra* is hard, dark tan in colour and corky; tan brown and patchy grainy in *F. glomerata*; soft, pale greyish and Scaly in *M. oleifera*. Internally it consists of three distinct structural zones viz., the conducting phloem, non-conducting phloem and periderm in all the three species. Major part of the adult bark is not conducting in nature, and is made up of mainly the axial parenchyma, ray parenchyma, sclerenchyma and occasionally a few deformed sieve elements in all the three investigated species (Plates- XII-D, XIII-C,D, XV-D).

In *C. pentandra*, sieve plates mostly oblique and simple, some are transverse, sieve areas scattered on the lateral walls of sieve-tube member. Each sieve-tube is accompanied by a companion cell having dense cytoplasm and prominent nucleus.

In *F. glomerata* sieve plates slightly oblique to transverse and simple, exhibit transverse arrangement, lateral sieve areas plenty, arranged in linear order. Each sieve-tube member accompanied by a companion cell which is very narrow and almost equal to the size of contiguous sieve-tube member.

In *M. oleifera* sieve plate simple, mostly transversely placed, sieve areas scattered over the entire lateral walls of sieve-tube members. Each sieve-tube member accompanied by

a latterly placed narrow companion cell with dense cytoplasm and prominent nucleus.

The conducting phloem adjacent to cambium has been analysed in order to find out the dimensional variations of sieve tube members and phloem fibres. The sieve-tube members are found to very in length from 162.50 – 450.00 μm in *C. pentandra*, 150.00 – 412.50 μm in *F. glomerata* and 187.50 - 400.00 μm in *M. oleifera* with an average of 324.42 μm, 266.08 μm 269.29 μm respectively. The radial and tangential diameters of sieve tube members is found varying from 25.00/12.50 – 87.50/87.50 μm in *C. pentandra*, 12.50/12.50 - 62.50/75.00 μm in *F. glomerata* and 12.50/12.50 - 50.00/50.00 μm in *M. oleifera* with an average of 46.79/45.42 μm, 29.59/33.29 μm and 27.98/29.40 μm in the respective species. Above observations clearly reveal that dimensions of sieve-tube members significantly differ in all the species investigated (Table 29).

The rays of the conducting phloem in tangential sections have been analysed and found that they vary in height from 1-70 cells in *C. pentandra*, 1-62 cells in *F. glomerata* and 1-22 cells in *M. oleifera,* while their width varies from 1-9, 1-20, and 1-3 cells respectively. The phloem rays have been classified into three groups based on their height viz. short (up to 300 μm), medium (301-600 μm) and tall (above 600 μm). An analysis of relative frequency of short, medium and tall rays has revealed that 23% short rays occur in *C. pentandra*, 14% in *F. glomerata* and about 56% in *M. oleifera*, while the medium ones constitute about 25%, 67% and 39% in the respective species. The tall rays dominated in *C. pentandra* and constitute about 52%, while in *F. glomerata* and *M.*

Table-29: Dimension of sieve-tube members and phloem fibres based on round the year collections (as seen in macerated sample) in the selected species.

Species		Mean Dimension of Sieve-Tube members (μm)			Mean Dimension of Phloem Fibres (μm)	
		Length	Radial Diameter	Tangential Diameter	Length	Width
C. pentandra	Range	162.50-450.00	25.00-87.50	12.50-87.50	650.00-2500.00	12.50-50.00
	Mean±S.E.	324.42 ±2.68	46.79±0.71	45.42±0.72	1489.63±22.76	26.31±0.31
	S.D.	46.43	12.33	12.44	394.13	5.31
	C.V.%	14.24	25.64	26.72	26.46	20.18
F. glomerata	Range	150.00-412.50	12.50-62.50	12.50-75.00	625.00-2300.00	12.50-37.50
	Mean±S.E.	266.08±3.31	29.59±0.47	33.29±0.60	1388.33±23.45	23.21±0.23
	S.D.	57.31	8.20	10.44	406.18	3.98
	C.V.%	21.21	27.01	30.87	29.26	17.16
M. oleifera	Range	187.50-400.00	12.50-50.00	12.50-50.00	250.00-1300.00	25.00-62.50
	Mean±S.E.	269.29±2.21	27.98±0.40	29.40±0.49	672.88±10.89	44.00±0.43
	S.D.	38.35	7.00	8.50	188.71	7.44
	C.V.%	13.57	25.01	28.90	28.31	17.09

oleifera, tall rays constitute 19% and 5% respectively. Similarly, the frequency of uniseriate, biseriate and multiseriate ray has been analysed and found that in *C. pentandra* about 22% rays are uniseriate, in *F. glomerata*, 2% and about 35% in *M. oleifera*. The biseriate constitute 18%, 9% and 56% respectively, while the multiseriate constitute 60% in C. *pentandra*, 89% in *F. glomerata* and 9% in *M. oleifera* (Fig.22 & 23).

A similar analysis of the non-conducting phloem has revealed that short rays constitute about 22% in *C. pentandra*, 21% in *F. glomerata* and about 52% in *M. oleifera* of the total count. The medium rays constitute about 28%, 63% and 43% respectively. The tall rays constitute about 50% in *C. pentandra*, 16% in *F. glomerata* and 5% in *M. oleifera*. In non-conducting phloem the relative abundance of uniseriate, biseriate and multiseriate rays has been analysed and it is noticed that uniseriate rays constitute about 13% in *C. pentandra*, 2% in *F. glomerata* and 25% in *M. oleifera*. The biseriate rays constitute about 13% in *C. pentandra*, 9% in *F. glomerata* and 55% in *M. oleifera* and multiseriate about 74%, 89% and 20% in the respective species (Fig.24 & 25). The height of the rays has been found to vary 1-70 cells in *C. pentandra*, 1-62 cells in *F. glomerata* and 1-22 cells in *M. oleifera*, while the width has been noticed to vary from 1-9, 1-20 and 1-3 cells respectively.

Microscopic examination of tangential sections passing through the bark, as well as the macerated fibre samples show that in all the three species studied, the bast fibre are of the libriform type. Their morphology and histochemical reactions to phloroglucinol and safranin indicate that they have under

gone apical elongation in the secondary phase of their differentiation after the first phase of their maturation. The intrusively grown apical parts are generally found possessing comparatively bigger lumen, rich in cytoplasmic contents and found having various types of structural manifestations, such as serrations, forking, hooks, bending etc. Their dimensional variations have been analysed and they have been found to vary in length 650.00-2500.00 μm in *C. pentandra*, 625.00-2300.00 μm in *F. glomerata* and 250.00 – 1300.00 μm in *M. oleifera* and in width from 12.50-50.00 μm, 12.50-37.50 μm and 25.00-62.50 μm respectively in the species investigated (Table 30). A comparison of average fibre length with that of their fusiform mother initials has shown that fibres have grown 4.30, 4.20 and 2.43 times over the length of their respective mother initials in *C. pentandra*, *F. glomerata* and *M. oleifera* respectively (Table 30).

Analysis of the conducting phloem of the different investigated species in transectional plane has revealed that the sieve tube elements occupy about 28% in *C. pentandra*, 25% in *F. glomerata* and 27% in *M. oleifera*. The ray parenchyma 30% in *C. pentandra*, about 31% both in *F.* glomerata and *M. oleifera*. Axial parenchyma 25%, 26% and 28%. Sclerenchyma 17%, 18%, and 14% of the total transectional area respectively (Fig.26). In tangential plane all the ray types together have been found to occupy about 44% area in *C. pentandra*, 35% in *F. glomerata* and 40% in *M. oleifera*. While in non-conducting phloem, rays occupy about 53% in *C. pentandra*, 50% in *F. glomerata* and 54% in *M. oleifera*, which clearly indicates that the phloem rays shows significant widening in non-conducting region of the bark (Figs.27 & 28).

Table-30: Average length and width of phloem fibres and their length comparison with mother initials (fusiform initials) in the selected species (based on round the year collections).

Species		Length of Fusiform Initials (μm)	Length of Phloem Fibres (μm)	Width of Phloem Fibres (μm)	Extent of growth of Phloem Fibres
C. pentandra	Range Mean±S.E. S.D. C.V.%	212.50-712.50 346.58 ±3.27 56.62 16.69	650.00-2500.00 1489.63±22.76 394.13 26.46	12.50-50.00 26.31±0.31 5.31 20.18	4.298
F. glomerata	Range Mean±S.E. S.D. C.V.%	150.00-612.50 330.71 ±5.38 93.25 28.62	625.00-2300.00 1388.33±23.45 406.18 29.26	12.50-37.50 23.21±0.23 3.98 17.16	4.198
M. oleifera	Range Mean±S.E. S.D. C.V.%	125.00-437.50 277.21 ±2.87 49.71 18.23	250.00-1300.00 672.88±10.89 188.71 28.31	25.00-62.50 44.00±0.43 7.44 17.09	2.427

Developmental changes in the structure of secondary phloem:

The structural changes of the phloem have been studied in the axes of different girth from the same tree at different height levels. The different components of the phloem including the sieve-tube members are found varying with the girth of the axes. The average length of sieve-tube members show a corresponding increase with the increase in the stem circumference in *C. pentandra* and *M. oleifera* while it declines near the base in case of *F. glomerata*. In current year shoots average length of sieve-tube members is recorded about 280.00 μm in *C. pentandra*, 196.50 μm in *F. glomerata* and 190.00 μm in *M. oleifera*, while in adult trunks, it is measured up to 358.00 μm in *C. pentandra*, 268.50 μm in *F.* glomerata and 279.50 μm in *M. oleifera* (Tables 31-33).

Studies on the lumen size of sieve-tube members have revealed that radial and tangential diameter shows a significant increase in size in the beginning and soon this gets almost stabilize and near the basal region lumen size exhibits a declining tendency in *C. pentandra*. In the case of *F. glomerata* lumen size shows a gradual increase with the age and more or less get stabilized at the base but in *M. oleifera* there is no doubt that there is an insignificant widening in the lumen size of sieve-tube members with the increasing age of the stem axis but at the basal region the lumen size remains almost constant and no significant variation is recorded during the course of the investigation (Tables 31-33).

The average radial and tangential diameter are measured 32.50/27.50 μm in *C. pentandra*, 20.50/19.00 μm in *F. glomerata* and 23.50/25.00 μm in *M. oleifera* in the current

Table-31: Changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Ceiba pentandra*.

Circumference of the axis in Cm.	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	225.00-400.00	280.00 ±9.27	46.34	16.55	25.00-50.00	32.50 ±1.61	8.07	24.83	12.50-50.00	27.50 ±1.61	8.07	29.34
55	200.00-437.50	316.00 ±12.25	61.23	19.38	37.50-75.00	50.00 ±2.04	10.21	20.41	37.50-75.00	55.50 ±2.17	10.87	19.59
80	250.00-450.00	340.00 ±8.84	44.19	12.99	25.00-62.50	48.50 ±1.95	9.76	20.13	25.00-75.00	55.50 ±2.29	11.46	20.64
105	175.00-412.50	342.50 ±10.41	52.04	15.19	37.50-62.50	54.50 ±1.59	7.97	14.63	37.50-62.50	52.00 ±1.87	9.33	17.94
150	287.50-450.00	358.00 ±7.74	38.70	10.81	37.50-75.00	42.50 ±2.04	10.21	24.01	25.00-62.50	47.00 ±1.95	9.74	20.72
F = 2.96, p<0.0					F = 25.32, p<0.01				F = 34.53, p<0.01			

Table-32: Changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Ficus glomerata*.

Circumference of the axis in Cm.	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	125.00-275.00	196.50 ±8.15	40.75	20.74	12.50-25.00	20.50 ±1.05	5.27	25.69	12.50-37.50	19.00 ±1.32	6.62	34.86
55	150.00-300.00	233.00 ±9.60	47.99	20.60	12.50-37.50	26.00 ±1.00	5.00	19.23	12.50	28.25 ±1.84	9.22	32.64
80	125.00-375.00	250.00 ±11.13	55.67	22.27	12.50-37.50	27.50 ±1.25	6.25	22.73	12.50-50.00	30.75 ±2.04	10.19	33.15
105	162.50-375.00	279.50 ±10.43	52.15	18.66	12.50-37.50	29.75 ±1.35	6.77	22.76	25.00-50.00	32.00 ±1.74	8.71	27.23
150	162.50-375.00	268.50 ±10.90	54.50	20.30	12.50-37.50	27.50 ±1.25	6.25	22.73	12.50-50.00	31.00 ±1.82	9.11	29.38
	$F = 10.45, p<0.01$				$F = 6.67, p<0.01$				$F = 9.05, p<0.01$			

Table-33: Changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) along the tree axis of varying girth in *Moringa oleifera*.

Circumference of the axis in Cm.	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
20	225.00-375.00	190.00 ±8.53	42.65	22.45	12.50-25.00	23.50± 0.83	4.15	17.64	12.50-50.00	25.00 ±1.97	9.87	38.70
55	150.00-337.50	237.00 ±9.05	45.25	19.09	25.00-37.50	27.50 ±1.02	5.10	18.56	12.50-37.50	26.00 ±1.23	6.17	23.72
80	225.00-337.50	275.00 ±6.08	30.39	11.05	18.75-37.50	28.25 ±1.20	6.02	21.30	12.50-37.50	27.00 ±1.56	7.81	28.91
105	212.50-325.00	278.00 ±5.55	27.74	9.98	25.00-37.50	28.50 ±1.15	5.73	20.10	12.50-37.50	29.50 ±1.42	7.11	24.09
150	225.00-375.00	279.50 ±7.11	35.56	12.75	25.00-50.00	29.50 ±1.42	7.11	24.09	12.50-50.00	29.50 ±1.59	7.97	27.02
F = 5.99, p<0.01					F = 4.14, p<0.01				F = 1.46, p is non-significant			

year shoots and 42.50/47.00 μm in *C. pentandra*, 27.50/31.00 μm in *F. glomerata* and 29.50/29.50 μm in *M. oleifera* in adult trunks (Tables 31-33).

In all the three species investigated, some of the sieve-tube members are found showing indications to have been grown intrusively. Such elements develop tail like bodies of varying size. The sieve-tube elements are always found smaller than the cambial cells from which they have developed in all the three species investigated.

The phloem fibres also exhibit changes in their dimension with the growing age of the tree axis. The average length of the fibres is found to vary from 1262.00 - 1502.50μm in *C. pentandra*, 994.50 - 1348.00 μm in *F. glomerata* and 487.50 - 675.00 μm in *M. oleifera* and their average width vary from 20.50 - 26.75 μm, 18.75 - 24.75 μm and 30.75 – 46.00 μm respectively (Tables 34-36).

The rays are found invariably taller and broader in the older trunks than in the younger shoots. As a consequence, the rays occupy greater area in older trunks than in younger ones. The tall and multiseriate rays in conducting phloem vary from 28-50% to 65-74% and in non-conducting phloem from 30-56% to 63-71% in *C. pentandra* and in *F. glomerata* tall and multiseriate rays in conducting phloem vary from 19-25% to 80-94% and in non-conducting phloem 12-23% to 86-95% from younger to older trunks. While in *M. oleifera* tall and multiseriate rays do not show any significant impact of age (Figs. 15-18).

Analysis of the transections of the phloem samples collected from the axis of varying age has revealed that they differ in their components to considerable extent in the

Table-34: Changes in the dimension of phloem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Ceiba pentandra*.

Circumference of the axis in Cm.	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	875.00-2062.50	1262.00±66.07	330.33	26.18	12.50-37.50	20.50±0.80	4.00	19.52
55	1050.00-2250.00	1300.50±68.55	342.74	26.37	25.00-37.50	24.10±063	3.13	12.97
80	1000.00-2400.00	1370.50±64.98	324.92	23.71	12.50-37.50	25.75±0.83	4.16	16.16
105	1125.00-2312.50	1453.00±68.44	342.20	23.55	18.75-37.50	26.75±0.66	3.29	12.29
150	1050.00-2437.00	1502.50±76.79	383.97	25.56	18.75-37.50	25.75±0.75	3.75	14.56
F = 1.74, p is non-significant					F = 0.14, p is not significant.			

Table-35: Changes in the dimension of phloem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Ficus glomerata*.

Circumference of the axis in Cm.	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	650.00-1337.50	994.50±44.22	221.09	22.23	18.75-25.00	18.75±0.61	3.06	16.33
55	637.50-1687.50	1225.00±63.67	318.34	25.99	12.50-31.25	23.75±0.72	3.61	15.19
80	687.50-1950.00	1279.00±79.71	398.54	31.16	18.75-25.00	23.50±0.54	2.72	11.59
105	800.00-2250.00	1348.00±85.74	428.72	31.80	18.75-37.50	24.75±0.92	4.59	18.56
150	625.00-2000.00	1221.50±74.03	370.17	30.30	18.75-31.25	23.25±0.68	3.39	14.56
	F = 3.50, p<0.01				F = 1.10, p is non-significant			

Table-36: Changes in the dimension of phloem fibres (as seen in macerated samples) along the tree axis of varying girth in the *Moringa oleifera*.

Circumference of the axis in Cm.	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
20	250.00-725.00	487.50±25.58	127.89	26.23	12.50-43.75	30.75±1.57	7.85	25.52
55	312.50-950.00	578.00±33.26	166.31	28.77	31.25-50.00	41.75±1.13	5.63	13.47
80	300.00-1200.00	600.00±41.93	209.64	34.94	31.25-62.50	46.00±1.34	6.72	14.61
105	375.00-1212.50	655.50±44.39	221.96	33.86	31.25-50.00	43.25±1.14	5.68	13.14
150	362.50-1150.00	675.00±36.97	184.84	27.38	31.25-62.50	44.50±1.54	7.72	17.35
F = 8.63, p<0.01					F = 20.03, p<0.01			

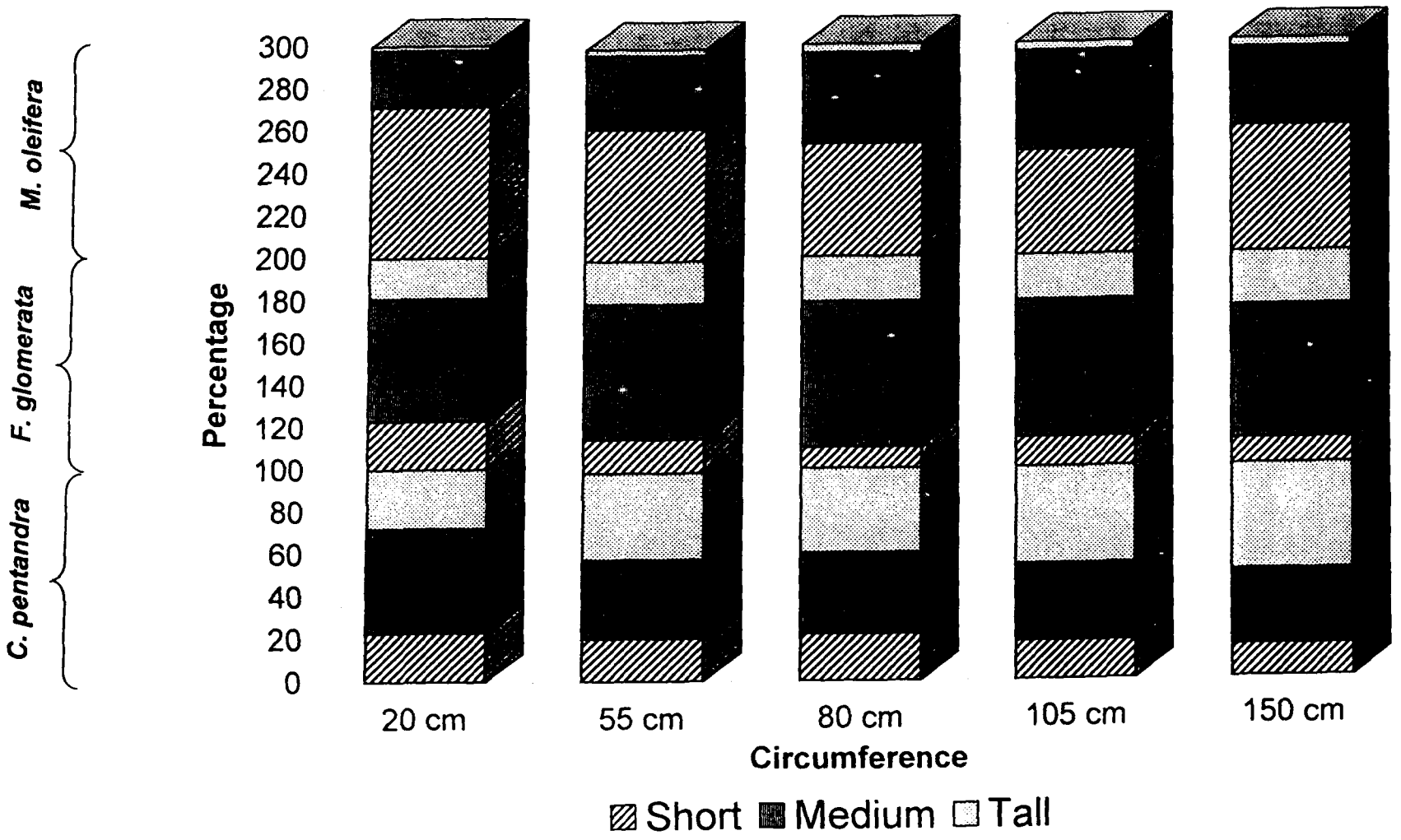


Figure-15: Percent conducting phloem rays.

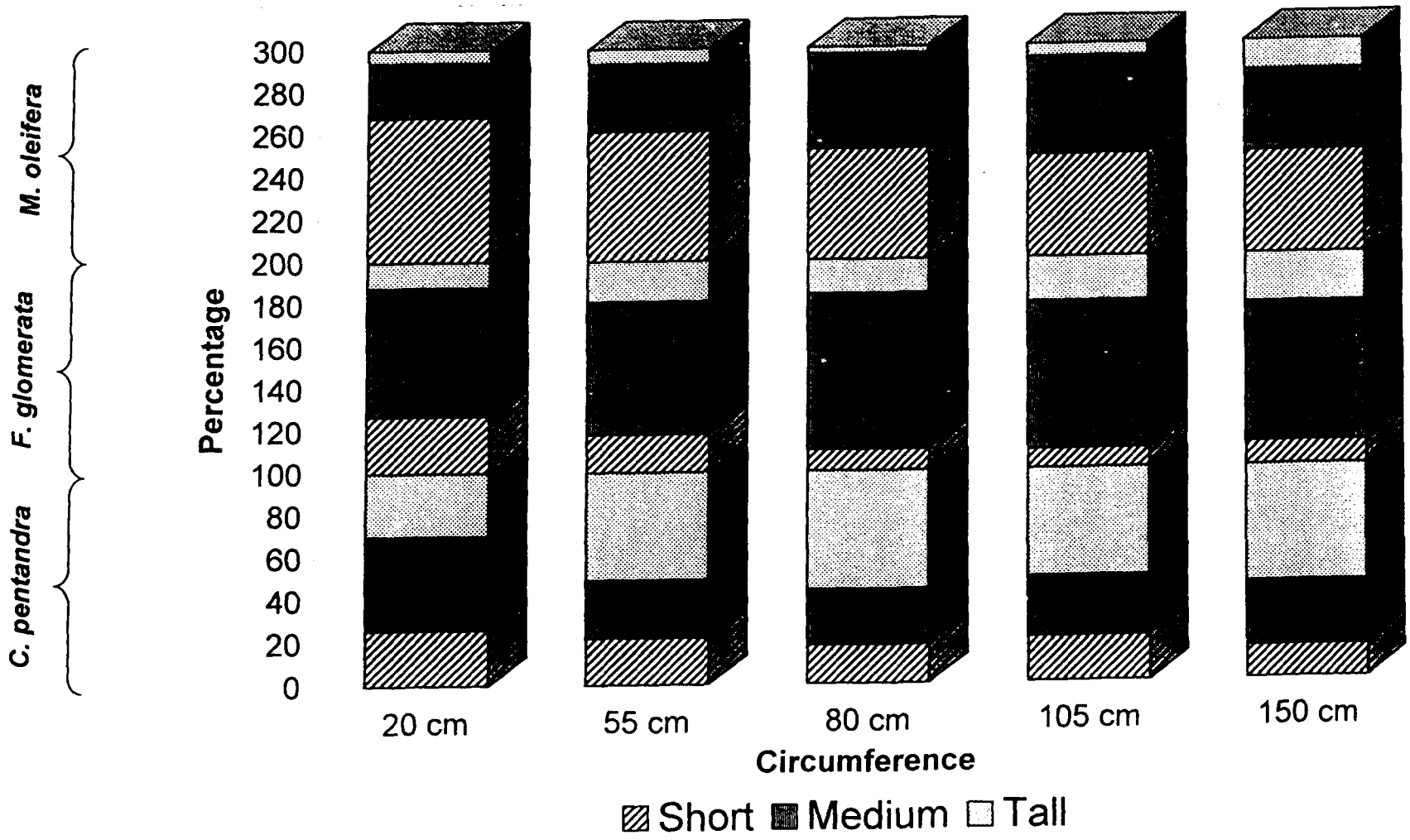


Figure-16: Percent non-conducting phloem rays.

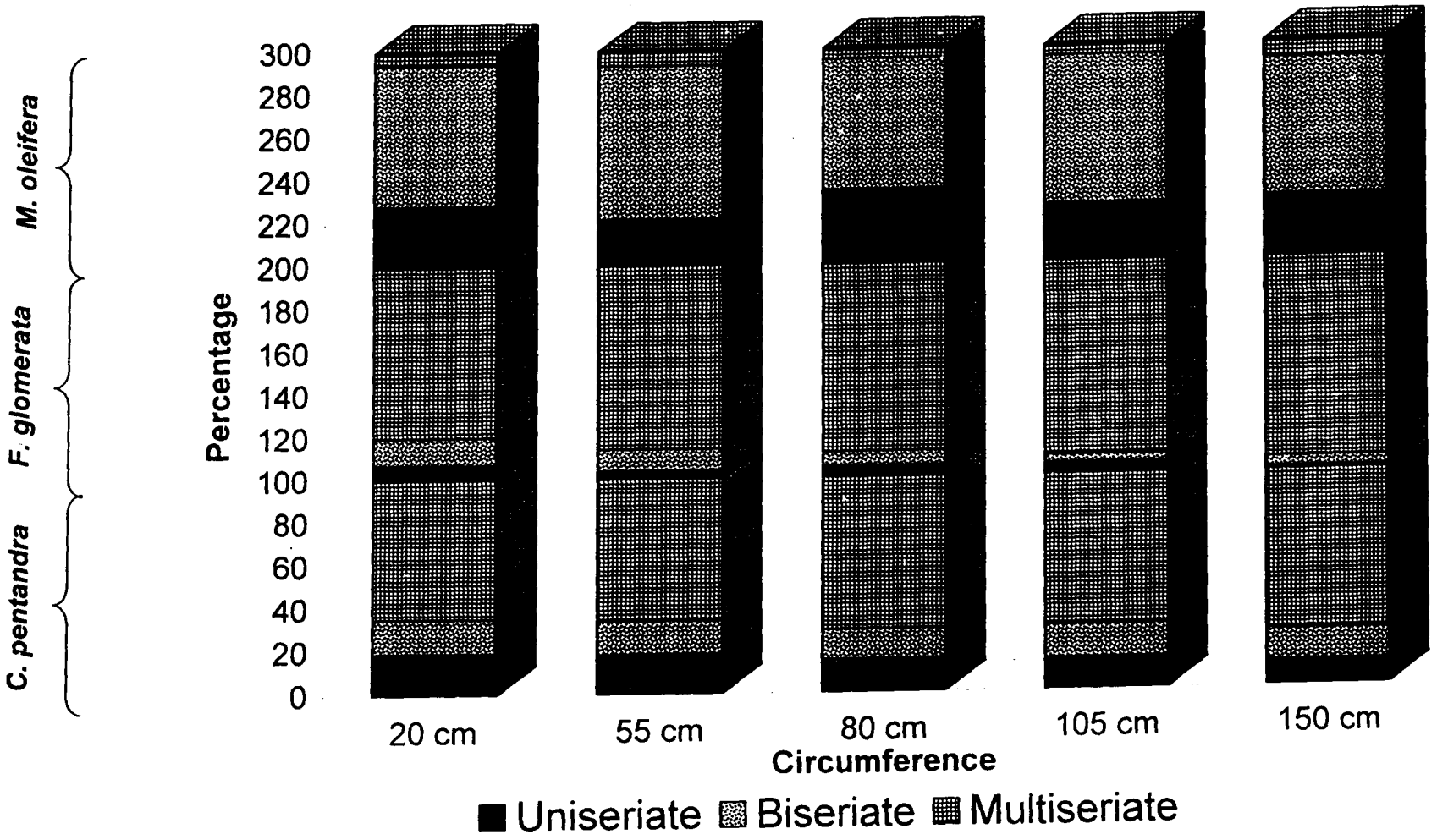


Figure-17: Percent conducting phloem rays.

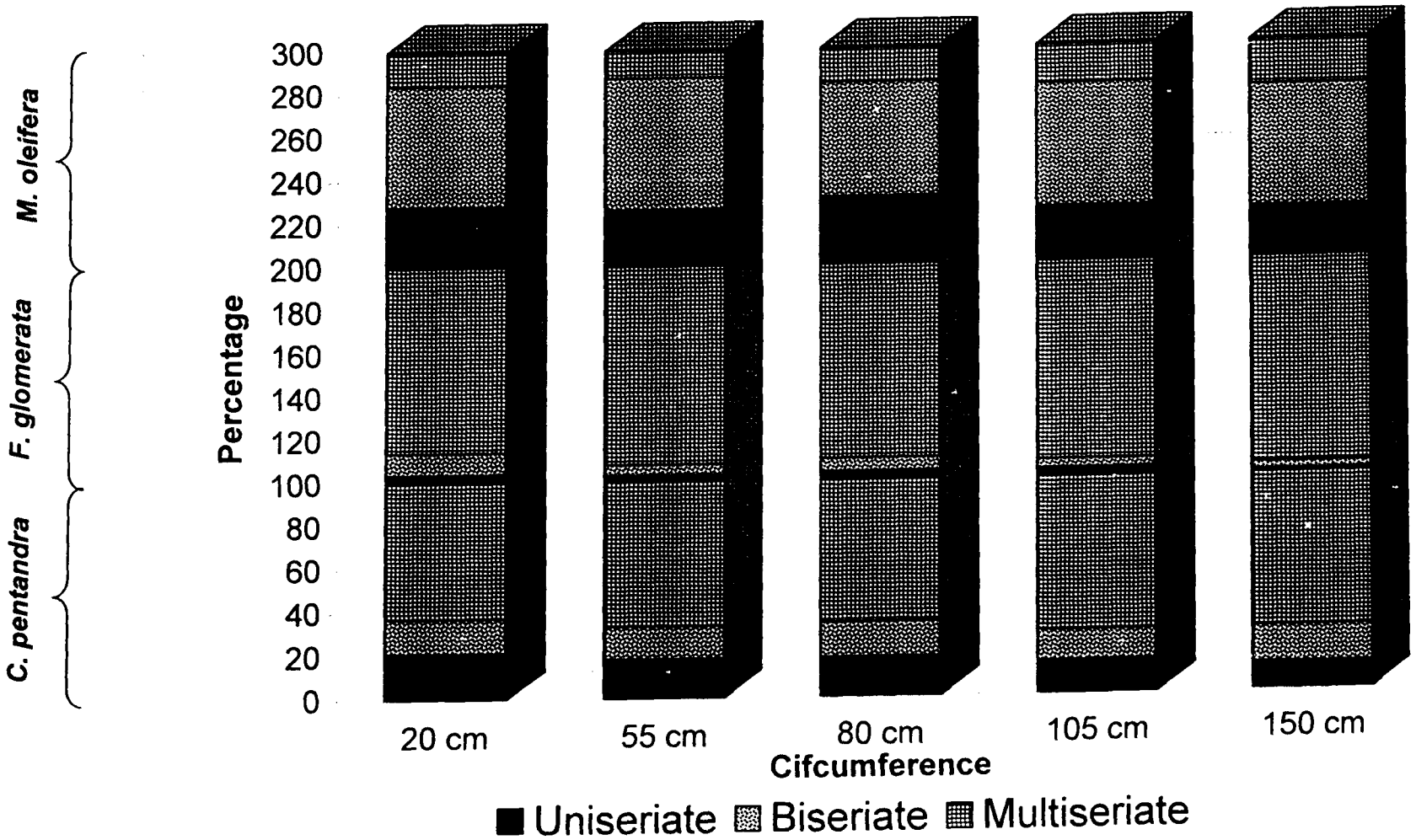


Figure-18: Percent non-conducting phloem rays.

different samples. The sieve tube area is noticed to vary from 24-30% in *C. pentandra* 25-29% in *F. glomerata* and 23-28% in *M. oleifera*, the ray parenchyma from 27-35%, 29-38% and 28-31% the axial parenchyma 18-22%, 22-28% and 24-29% and sclerenchyma 19-25%, 9-20%, and 17-20% in the respective species (Fig.19). The amount of sieve-tubes is found increasing with increase in diameter of the tree axis in all species investigated. The sclerenchyma also exhibit an increasing tendency in *C. pentandra* and *F. glomerata* but it shows inconsistent behaviour in *M. oleifera*. Analysis of the tangential longitudinal sections of conducting phloem of shoots of varying age groups have revealed that the percentage area occupied by rays vary from 37-45% in *C. pentandra*, 34-40% in *F. glomerata*, 37-40% in *M. oleifera*. While in non-conducting phloem it varies from 45-57%, 41-48% and 47-54% respectively in the species investigated (Figs.20 & 21).

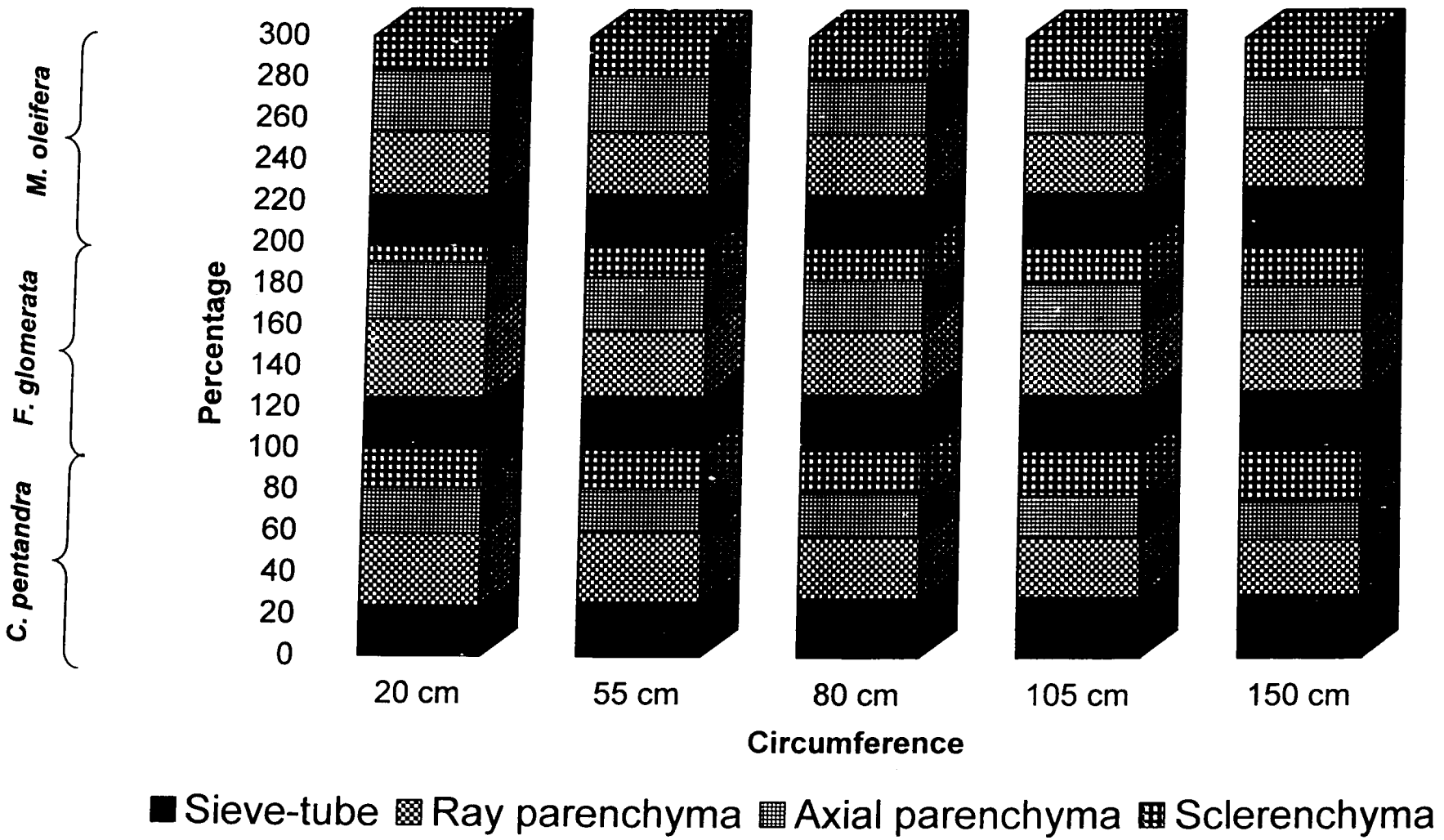


Figure-19: Percent transectional area in conucting phloem.

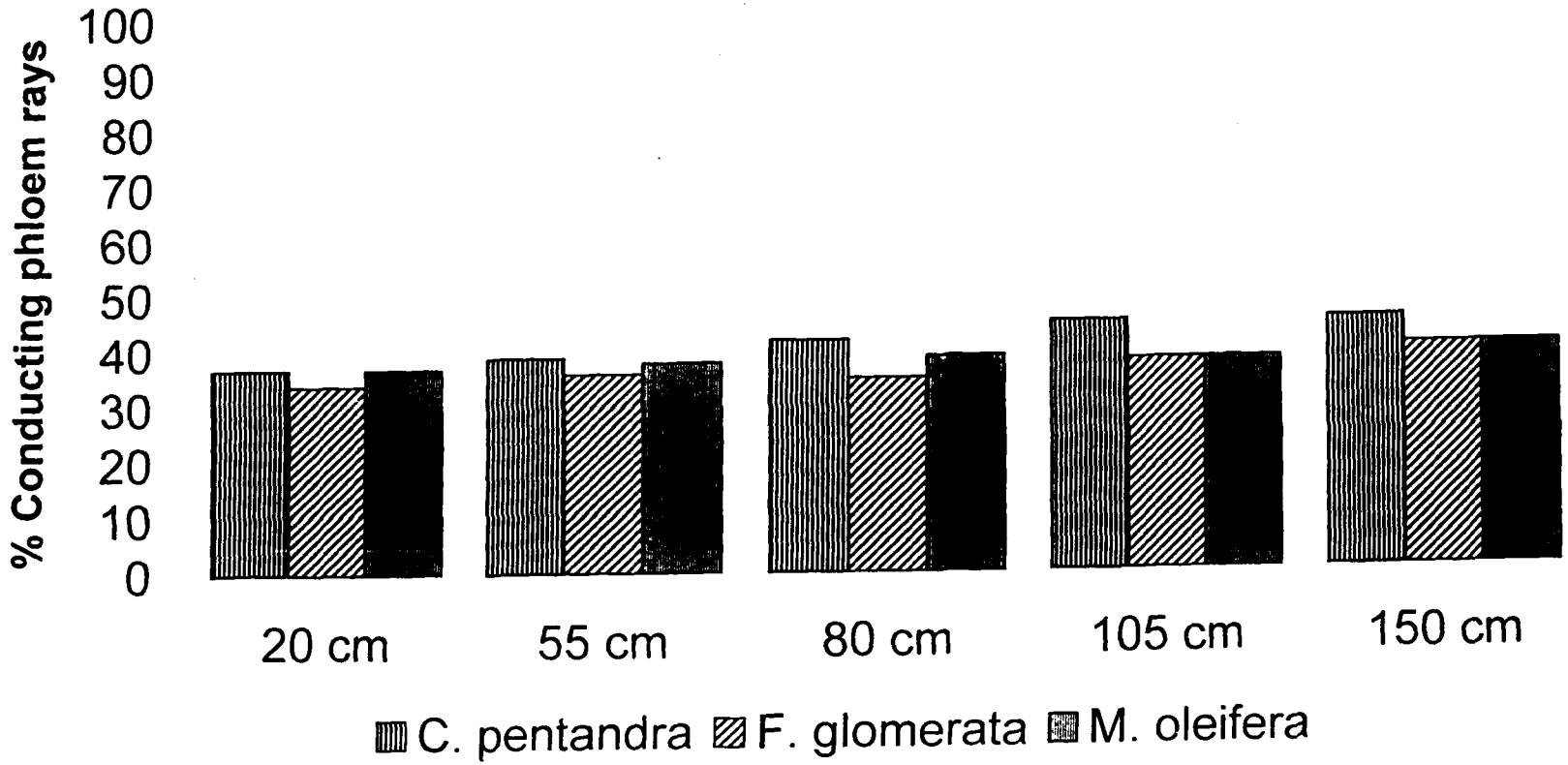


Figure-20: Percent tangential area (conducting phloem rays).

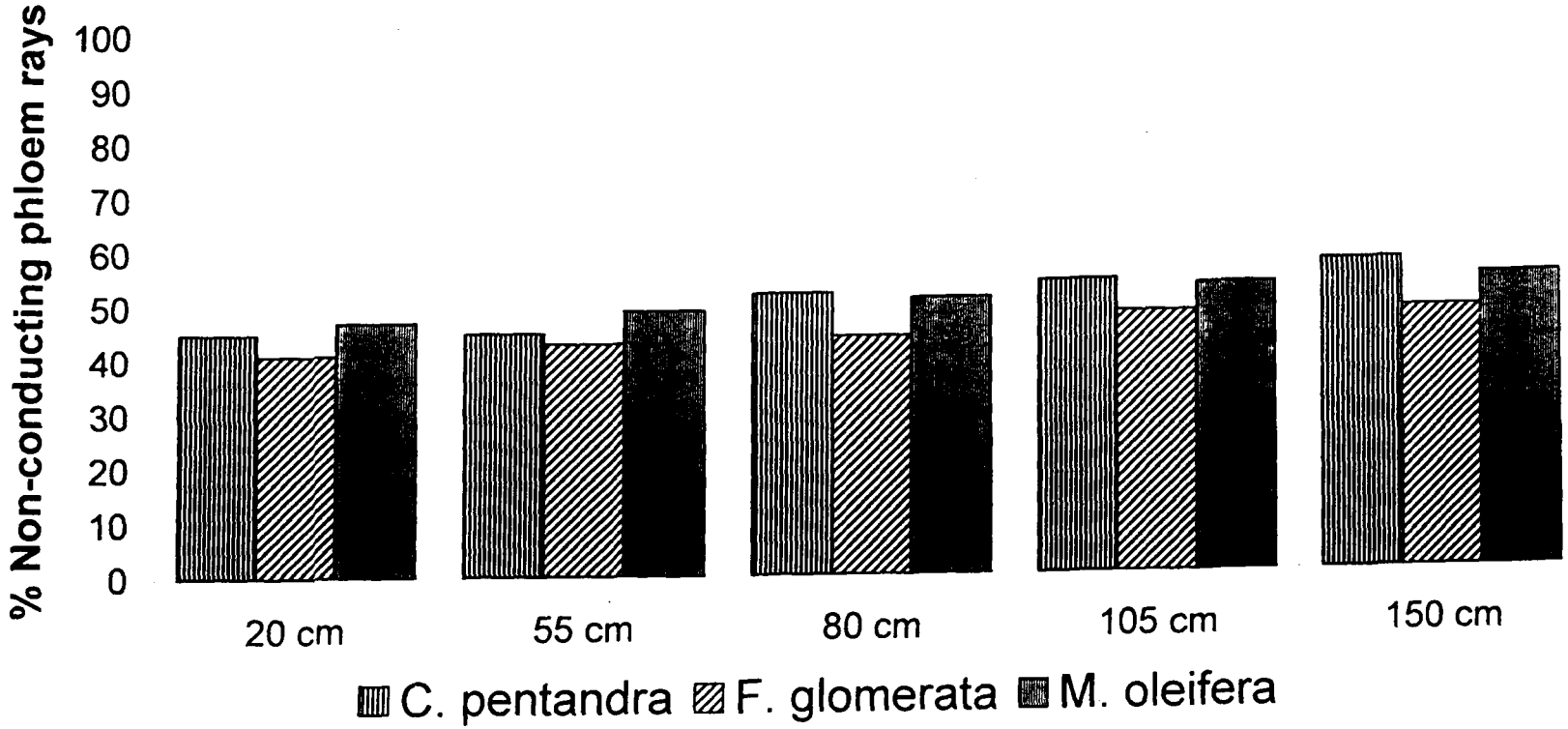


Figure-21: Percent tangential area (non-conducting phloem rays).

Seasonal changes in the structure of secondary phloem:

Various components of the conducting phloem have been analysed in the monthly collections in order to find out the dimensional variations in the size of sieve-tube members, sclerenchyma, axial and ray parenchyma, produced in different seasons. The mean length of sieve-tube members varies from 309.50 - 345.00 μm in *C. pentandra*, 210.50 - 283.00 μm in *F. glomerata* and 251.50 - 286.00 μm in *M. oleifera* (Tables 37-39). Comparatively longer elements occur more frequently in February, April, September and December and short ones in the rest of months in *C. pentandra*. In *F. glomerata*, the longer elements are found in March, May, October and November and short ones in other months while in *M. oleifera* comparatively longer elements occur in January, July, August and November and shorter ones in the rest of months. Insignificant changes in the lumen size of the sieve tube members have been noticed in all different seasons in the species investigated.

Observations on phloem fibres in secondary phloem have revealed that fibres undergo minor changes in different seasons. They are found to vary in length from 650.00 - 2500.00 μm in *C. pentandra*, 625.00 – 2300.00 μm in *F. glomerata* and 250.00 - 1300.00 μm in *M. oleifera* with an average varying from 1353.50 - 1607.50 μm, 1207.00 - 1627.00 μm and 598.50 - 778.50 μm respectively in the species investigated. Average width of phloem fibres is found varying from 24.50 - 27.25 μm in *C. pentandra* 21.75 - 24.50 μm in *F. glomerata* and 34.00 - 50.25 μm in *M. oleifera* (Tables 40-42). It is evident from the data obtained in this regard that longer fibres occur more frequently in September and October in *C. pentandra*, March and August in *F. glomerata* and in

Table-37: Seasonal changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Ceiba pentandra*.

Months	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	212.50-387.50	315.00 ±8.84	44.19	14.03	37.50-87.50	48.00 ±2.27	11.36	23.68	37.50-87.50	47.00 ±2.47	12.33	26.24
February	287.50-450.00	345.00 ±7.74	38.70	11.22	25.00-62.50	48.50 ±1.95	9.76	20.13	25.00-62.50	47.00 ±1.95	9.74	20.72
March	225.00-387.50	315.50 ±8.91	44.53	14.11	37.50-75.00	52.50 ±2.28	11.41	21.74	25.00-62.50	48.50 ±2.20	11.02	22.71
April	187.50-412.50	338.00 ±9.06	45.28	13.40	25.00-62.50	44.00 ±1.63	8.16	18.56	12.50-62.50	45.50 ±2.88	14.38	31.60
May	250.00-375.00	315.50 ±7.51	37.55	11.90	25.00-62.50	42.00 ±2.38	11.90	28.34	12.50-62.50	41.50 ±2.77	13.84	33.36
June	187.50-412.50	322.00 ±9.74	48.72	15.13	25.00-62.50	40.00 ±2.60	13.01	32.53	25.00-75.00	41.50 ±2.57	12.87	31.01
July	187.50-412.50	323.50 ±10.86	54.29	16.78	25.00-75.00	49.50 ±2.65	13.25	26.76	25.00-62.50	46.50 ±2.34	11.70	25.17
August	225.00-400.00	309.50 ±7.98	39.90	12.89	25.00-62.50	48.00 ±2.00	10.00	20.83	25.00-62.50	46.00 ±2.13	10.66	23.16
September	250.00-425.00	332.00 ±8.51	42.56	12.82	25.00-75.00	48.00 ±2.00	10.00	20.83	12.50-62.50	45.50 ±2.27	11.34	24.93
October	237.50-437.50	321.50 ±9.03	45.14	14.04	25.00-62.50	49.00 ±2.03	10.16	20.72	25.00-62.50	47.50 ±2.17	10.83	22.79
November	162.50-400.00	322.00 ±9.80	48.98	15.21	25.00-62.50	40.50 ±2.31	11.57	28.57	25.00-50.00	39.50 ±1.72	8.60	21.77
December	237.50-425.00	335.50 ±9.54	47.70	14.30	37.50-62.50	51.50 ±1.81	9.07	17.61	25.00-62.50	49.00 ±2.03	10.56	20.72
	F = 2.72, p<0.01				F = 8.57, p<0.01				F = 5.24, p<0.01			

Table-38: Seasonal changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Ficus glomerata*.

Months	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	225.00-412.50	265.00 ±11.06	55.32	20.87	25.00-50.00	29.70 ±1.35	6.75	22.73	25.00-62.50	35.20 ±1.72	8.60	24.43
February	162.50-375.00	268.50 ±10.90	54.50	20.29	12.50-37.50	27.60 ±1.30	6.36	23.05	12.50-50.00	31.00 ±1.82	9.11	29.38
March	187.50-400.00	283.00 ±10.07	50.37	17.80	18.75-50.00	32.50 ±1.49	7.44	22.89	25.00-62.50	35.75 ±2.21	11.05	30.91
April	150.00-375.00	264.50 ±10.52	52.62	19.90	12.50-37.50	30.00 ±1.44	7.22	24.06	12.50-50.00	35.50 ±1.83	9.15	25.77
May	175.00-375.00	274.00 ±9.27	46.34	16.91	12.50-37.50	24.50 ±1.14	5.68	23.19	12.50-50.00	31.75 ±2.04	10.19	32.10
June	175.00-375.00	271.00 ±11.72	58.60	21.62	12.50-37.50	28.50 ±1.35	6.77	23.75	12.50-50.00	31.75 ±2.22	11.11	35.00
July	175.00-387.50	262.50 ±10.56	52.79	20.11	18.75-37.50	28.75 ±1.25	6.25	21.74	12.50-37.50	25.50 ±1.25	6.23	24.42
August	162.50-312.50	210.50 ±7.66	38.30	18.20	25.00-37.50	32.50 ±1.25	6.25	19.23	25.00-50.00	39.00 ±1.66	8.32	21.34
September	175.00-387.50	266.00 ±12.30	61.50	23.12	25.00-62.50	34.00 ± 1.98	9.90	29.10	25.00-75.00	40.00 ±2.04	10.21	25.52
October	162.50-387.50	276.00 ±11.48	57.39	20.79	25.00-50.00	32.50 ±1.77	8.84	27.20	18.75-50.00	32.25 ±1.83	9.14	28.35
November	150.00-412.50	281.50 ±12.00	59.96	21.30	25.00-50.00	29.50 ±1.75	8.75	29.66	12.50-50.00	35.00 ±2.13	10.67	30.50
December	175.00-375.00	270.50 ±10.58	52.90	19.55	12.50-37.50	25.00 ±1.44	7.22	28.87	12.50-50.00	26.75 ±1.71	8.56	32.01
	F = 4.74, p<0.01				F = 7.27, p<0.01				F = 2.77, p<0.01			

Table-39: Seasonal changes in the length of sieve-tube members (as seen in macerated samples) and size of lumen (as seen in transectional view) in *Moringa oleifera*.

Months	Length of Sieve-Tube Members (μm)				Diameter of Sieve-Tube Members (μm)							
					Radial Diameter				Tangential Diameter			
	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%	Range	Mean ±S.E.	S.D.	C.V.%
January	237.50-337.50	285.50 ±5.40	27.00	9.46	18.75-50.00	30.00 ±1.69	8.46	28.21	18.75-50.00	30.75 ±1.84	9.19	29.87
February	225.00-375.00	270.00 ±7.11	35.56	13.17	25.00-50.00	29.50 ±1.42	7.11	24.09	12.50-37.50	27.00 ±1.56	7.81	28.91
March	225.00-387.00	264.00 ±9.61	48.07	18.21	12.50-50.00	30.00 ±2.04	10.21	34.02	18.75-50.00	30.50 ±1.50	7.51	24.62
April	212.50-387.50	265.00 ±8.75	43.73	16.50	18.75-37.50	27.25 ±1.13	5.67	20.81	25.00-37.50	28.75 ±1.14	5.71	19.85
May	212.50-400.00	255.00 ±9.10	45.52	17.82	18.75-37.50	29.50 ±1.28	6.38	21.64	25.00-50.00	33.00 ±1.75	8.75	26.52
June	225.00-375.00	260.00 ±7.56	37.82	14.55	12.50-50.00	26.75 ±1.47	7.33	27.41	25.00-50.00	33.25 ±1.79	8.97	26.98
July	187.50-387.50	283.00 ±9.87	49.36	17.44	12.50-37.50	26.25 ±1.02	5.10	19.44	12.50-50.00	27.00 ±1.68	8.41	31.14
August	225.00-362.50	286.00 ±7.42	37.10	12.97	12.50-37.50	26.00 ±1.00	5.00	19.23	12.50-37.50	26.50 ±1.36	6.82	25.73
September	212.50-337.50	266.50 ±6.38	31.93	11.98	12.50-37.50	24.25 ±1.37	6.83	28.15	12.50-50.00	27.75 ±1.95	9.73	35.06
October	225.00-337.50	251.50 ±6.42	32.10	12.76	18.75-37.50	28.50 ±1.35	6.77	23.75	12.50-50.00	32.25 ±2.03	10.16	31.49
November	225.00-337.50	274.00 ±5.88	29.42	10.74	18.75-37.50	29.75 ±1.31	6.57	22.10	12.50-37.50	28.50 ±1.54	7.67	26.92
December	187.50-325.00	270.50 ±6.13	30.64	11.33	25.00-37.50	28.00 ±1.09	5.45	19.46	12.50-37.50	27.50 ±1.61	8.07	29.34
	F = 1.42, p is not significant				F = 1.87, p<0.05				F = 2.18, p <0.01			

Table40: Seasonal changes in the dimension of phloem fibres (as seen in macerated samples) in the *Ceiba pentandra*.

Months	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	875.50-2250.00	1411.50±78.53	392.67	27.82	12.50-37.50	24.50±1.02	5.08	20.72
February	1050.00-2437.50	1502.50±76.79	383.98	25.56	18.75-37.50	25.75±0.75	3.75	14.56
March	750.00-2125.00	1353.50±72.94	364.71	26.95	12.50-31.25	24.50±0.95	4.75	19.37
April	875.00-2300.00	1421.50±73.49	367.43	25.85	12.50-43.75	26.00±1.00	5.00	19.23
May	687.50-2375.00	1463.50±72.78	363.88	24.86	25.00-37.50	26.50±0.75	3.73	14.09
June	1050.00-2000.00	1436.00±55.45	277.27	19.31	12.50-50.00	27.00±1.38	6.92	25.64
July	1125.00-2312.50	1557.50±78.43	392.16	25.18	12.50-50.00	27.25±1.34	6.72	24.67
August	875.00-2500.00	1545.00±98.37	491.83	31.83	18.75-43.75	26.00±0.86	4.30	16.54
September	1050.00-2500.00	1600.50±84.08	420.39	26.27	25.00-50.00	27.00±1.07	5.33	19.73
October	800.00-2250.00	1607.50±92.45	462.26	28.76	12.50-50.00	27.00±1.29	6.43	23.83
November	925.00-2312.50	1547.00±79.19	395.95	25.59	25.00-43.75	27.00±0.94	4.68	17.32
December	650.00-2150.00	1429.50±73.92	369.59	25.85	18.75-50.00	27.25±1.19	5.95	21.84
F = 1.08, p is non-significant					F = 1.13, p is non-significant			

Table-41: Seasonal changes in the dimension of phloem fibres (as seen in macerated samples) in the *Ficus glomerata*.

Months	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	937.50-2262.50	1420.00±75.45	377.26	26.57	12.50-25.00	21.75±0.73	3.66	16.84
February	625.00-2000.00	1221.50±74.03	370.17	30.30	18.75-31.25	23.25±0.68	3.39	14.56
March	800.00-2250.00	1627.00±71.84	359.21	22.08	12.50-31.25	23.50±0.83	4.15	17.64
April	850.00-2087.50	1361.50±73.11	365.56	26.85	12.50-31.25	23.25±0.85	4.24	18.23
May	687.50-2300.00	1207.00±88.54	442.71	36.68	12.50-25.00	22.25±0.81	4.06	18.27
June	850.00-2000.00	1386.00±79.34	396.72	28.62	12.50-31.25	23.75±1.02	5.10	21.49
July	725.00-2225.00	1385.50±91.56	457.78	33.04	12.50-25.00	22.50±0.81	4.03	17.93
August	987.50-2275.00	1591.50±80.89	404.43	25.41	12.50-37.50	24.50±0.88	4.39	17.92
September	812.50-2125.00	1473.00±90.83	454.13	30.83	12.50-31.25	23.75±0.72	3.61	15.19
October	850.00-2050.00	1446.00±75.48	377.42	26.10	12.50-31.25	23.50±0.83	4.15	17.64
November	812.50-2150.00	1324.50±66.20	331.00	24.99	12.50-25.00	23.50±0.65	3.27	13.90
December	625.00-1750.00	1216.50±67.92	339.61	27.92	12.50-25.00	23.00±0.70	3.48	15.13
		F = 3.03, p<0.01				F = 0.87, p is non-significant		

Table-42: Seasonal changes in the dimension of phloem fibres (as seen in macerated samples) in the *Moringa oleifera*.

Months	Length of Phloem Fibers (μm)				Width of Phloem Fibers (μm)			
	Range	Mean±S.E.	S.D.	C.V.%	Range	Mean±S.E.	S.D.	C.V.%
January	362.50-1150.00	634.00±35.19	175.95	27.75	37.50-62.50	48.50±1.31	6.57	13.56
February	375.00-1212.50	778.50±44.39	221.96	28.51	31.25-62.50	44.50±1.54	7.72	17.35
March	400.00-1250.00	761.50±40.79	203.96	26.78	37.50-62.50	48.50±0.97	4.87	10.04
April	425.00-1025.00	615.50±29.30	146.50	23.80	37.50-62.50	50.25±1.05	5.25	10.46
May	375.00-1162.50	684.00±36.22	181.12	26.48	37.50-62.50	48.00±1.13	5.63	11.72
June	462.00-1275.00	685.00±40.38	201.91	29.48	37.50-56.25	46.25±1.02	5.10	11.03
July	387.50-1112.50	687.50±33.32	166.58	24.23	31.25-50.00	45.25±1.10	5.50	12.15
August	462.50-1300.00	714.00±37.74	188.72	26.43	37.50-50.00	44.25±1.02	5.08	11.47
September	300.00-1125.00	620.50±39.36	196.78	31.71	25.00-43.75	42.50±1.19	5.96	14.03
October	337.50-1100.00	657.00±34.03	170.14	25.90	25.00-43.75	40.00±0.95	4.75	11.87
November	350.00-962.50	638.50±30.74	153.68	24.07	25.00-43.75	34.00±0.95	4.75	13.96
December	250.00-800.00	598.50±26.91	134.53	22.48	25.00-43.75	36.00±0.83	4.15	11.52
F = 3.63, p<0.01					F = 23.20, p<0.01			

February, March and August in *M. oleifera*, while short ones in the rest of the months.

The phloem rays have been found to vary in both conducting as well as non-conducting phloem in height and width in all the three investigated species. Microscopic examination of the immediate phloic derivatives in fortnightly collections during a calendar year has shown that the short rays vary from 18-30% in *C. pentandra*, 11-19% in *F. glomerata* and 46-64% in *M. oleifera*, the medium from 18-38%, 50-77% and 33-50% and tall from 43-58%, 9-35% and 3-10% respectively (Fig.22). A similar analysis of their width has revealed that the uniseriate rays vary from 16-30% in *C. pentandra*, 1-5% in *F. glomerata* and 25-50% in *M. oleifera*, the biseriate 13-24%, 5-17% and 41-70% and multiseriate, 52-69%, 81-94% and 2-16% respectively (Fig.23).

In *C. pentandra* short rays occur more frequently from August to October, the medium in January, February and April while the taller ones in March, May, June, September and November. In *F. glomerata* the maximum percentage of short rays is found in July, August and December, the medium in April, May and December and of the taller rays in March. *In M. oleifera* short rays occur more frequently in April and September while medium in October and November and tall rays dominated in July, August and December (Fig.22).

More or less similar trend of variation of short, medium and tall rays has been noticed in non-conducting phloem of all the presently investigated species (Fig.24).

In *C. pentandra* the uniseriate rays are found dominating in August and October, biseriate and February, April and June while multiseriate in March, November and December. In *F.*

glomerata higher frequency of uniseriate rays is found in March and December while biseriate in January, March, October and November and maximum percentage of multiseriate rays occur in February, May and June. In *M. oleifera* uniseriate rays dominated from June to August, biseriate in February, March and December, while multiseriate from August to October (Fig.23).

However, width of the rays shows a significant change in non-conducting phloem as compared to the conducting one in *C. pentandra* and *M. oleifera*. In *C. pentandra* conducting phloem has 52-69% multiseriate rays are found but in non-conducting phloem it ranges between 68-80%. In *M. oleifera* the conducting phloem have 2-16% multiseriate rays while in non-conducting phloem it ranges between 16-26%. In *F. glomerata* the frequency of multiseriate rays both in conducting and non-conducting phloem is almost same and varies from 81-94% in conducting phloem and 84-93% in non-conducting phloem (Figs.23 & 25).

Estimation of different components of the conducting phloem, in round year collection, has shown that the sieve tube area varies 25-30% in *C. pentandra*, 21-32% in *F. glomerata* and 23-30% in *M. oleifera*, the ray parenchyma 25-39%, 25-38% and 25-36%, axial parenchyma from 20-35%, 21-31% and 24-33% and sclerenchyma from 11-22%, 14-23% and 10-19% respectively (Fig.26).

They are occupied by sieve-tube members in transverse plane is found expressing minor fluctuation in the species presently investigated. The maximum transactional sieve-tube area has been found in December i.e. about 30% in *C. pentandra*, in January and October i.e. about 32% in *F.*

glomerata and in August i.e. about 30% in *M. oleifera*. A comparative look on the data summarized in figure 26 clearly reveals that sieve-tube members do not show any significant seasonal variation in all the three species investigated.

Estimation of the ray area of conducting phloem in tangential plane in round year collections has shown that it varies from 36-51% in *C. pentandra*, 30-43% in *F. glomerata* and 34-45% in *M. oleifera.* A similar analysis of the non-conducting phloem has shown that the area occupied by rays varies from 42-62% in *C. pentandra*, 44-57% in *F. glomerata* and 44-59% in *M. oleifera*. On the basis of above data it can be concluded that the rays occupy a relatively greater area in the non-conducting phloem in all the presently investigated species (Fig.27 & 28).

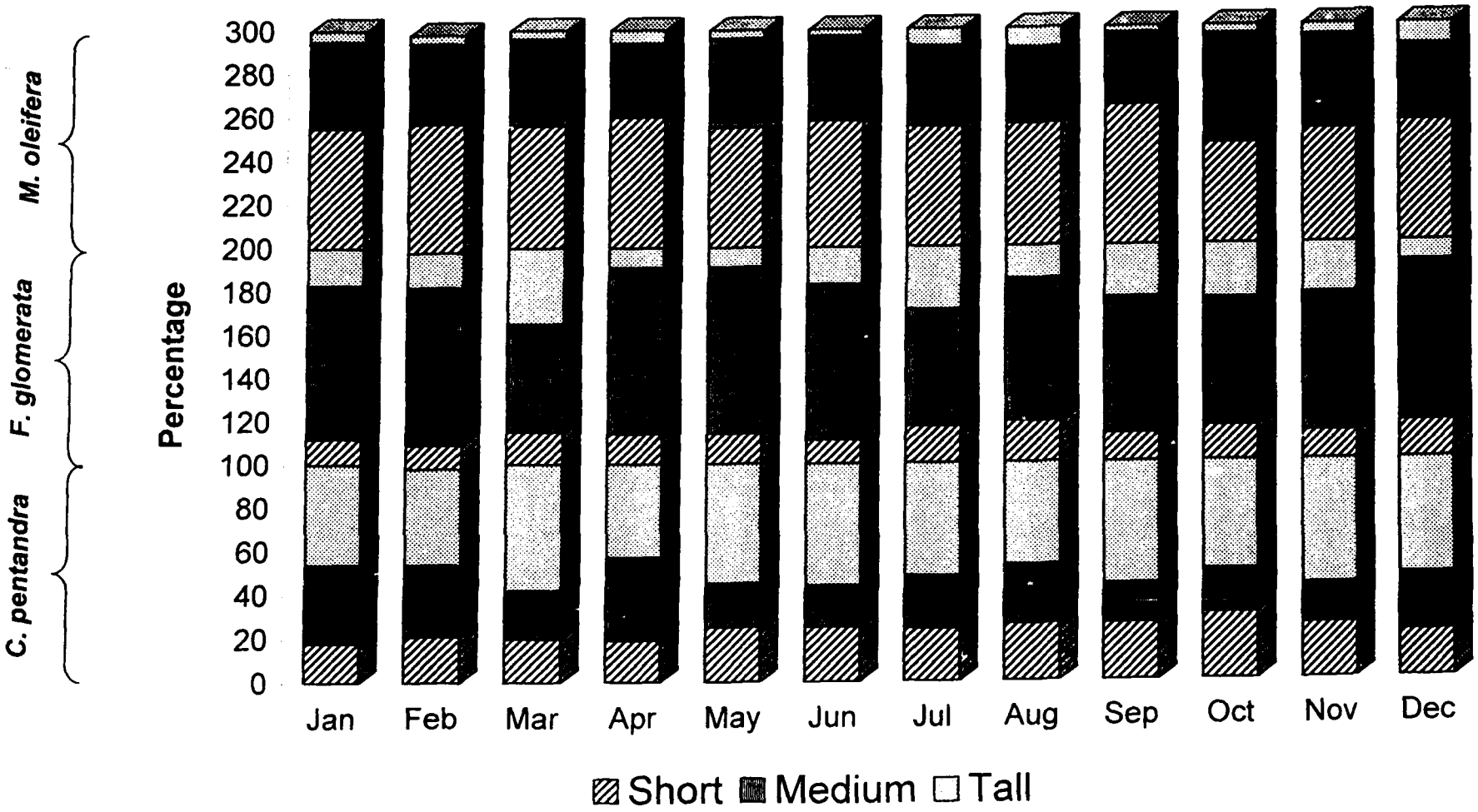


Figure-22: Percent rays in conducting phloem.

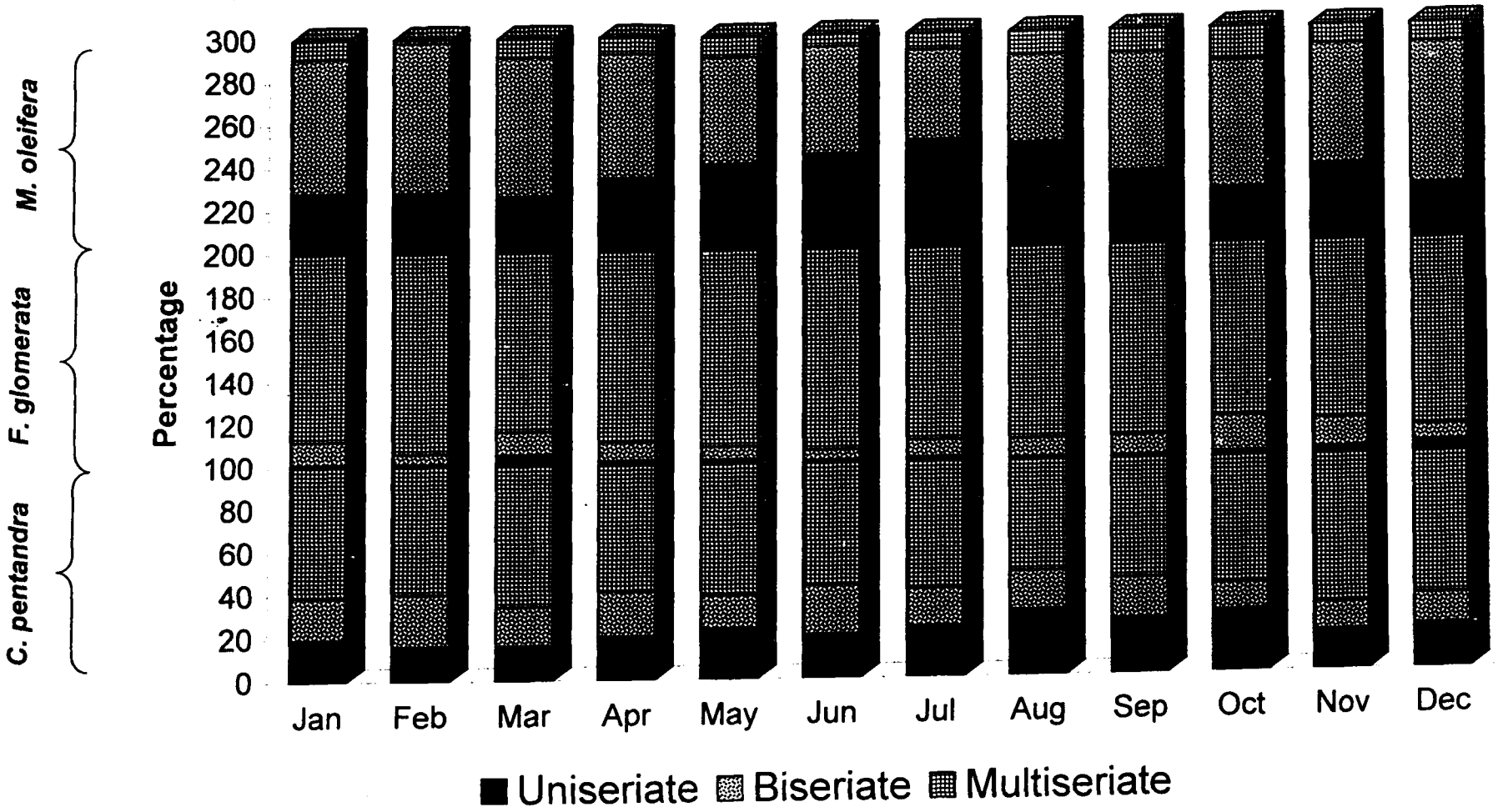


Figure-23: Percent rays in conducting phloem.

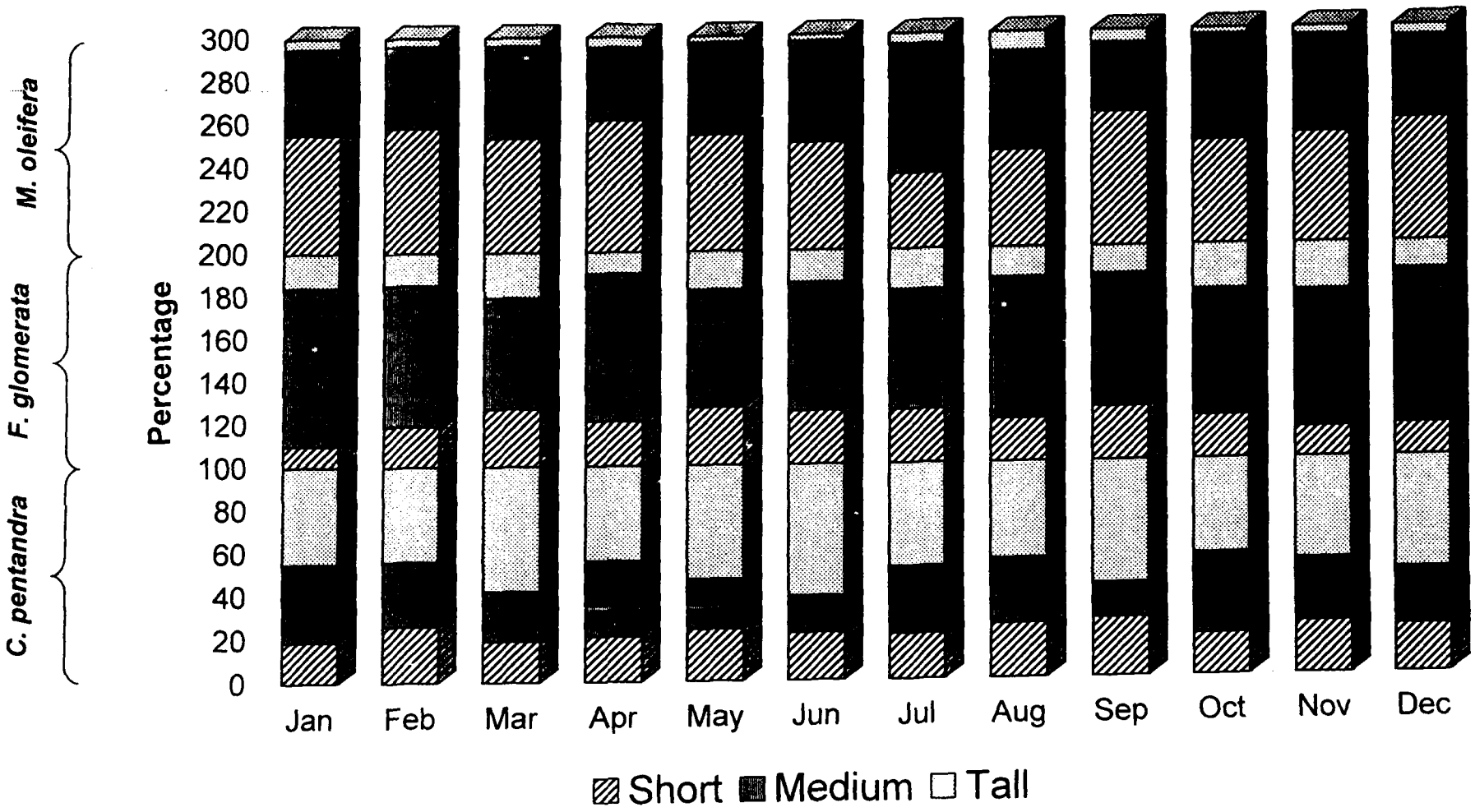


Figure-24: Percent rays in non-conducting phloem.

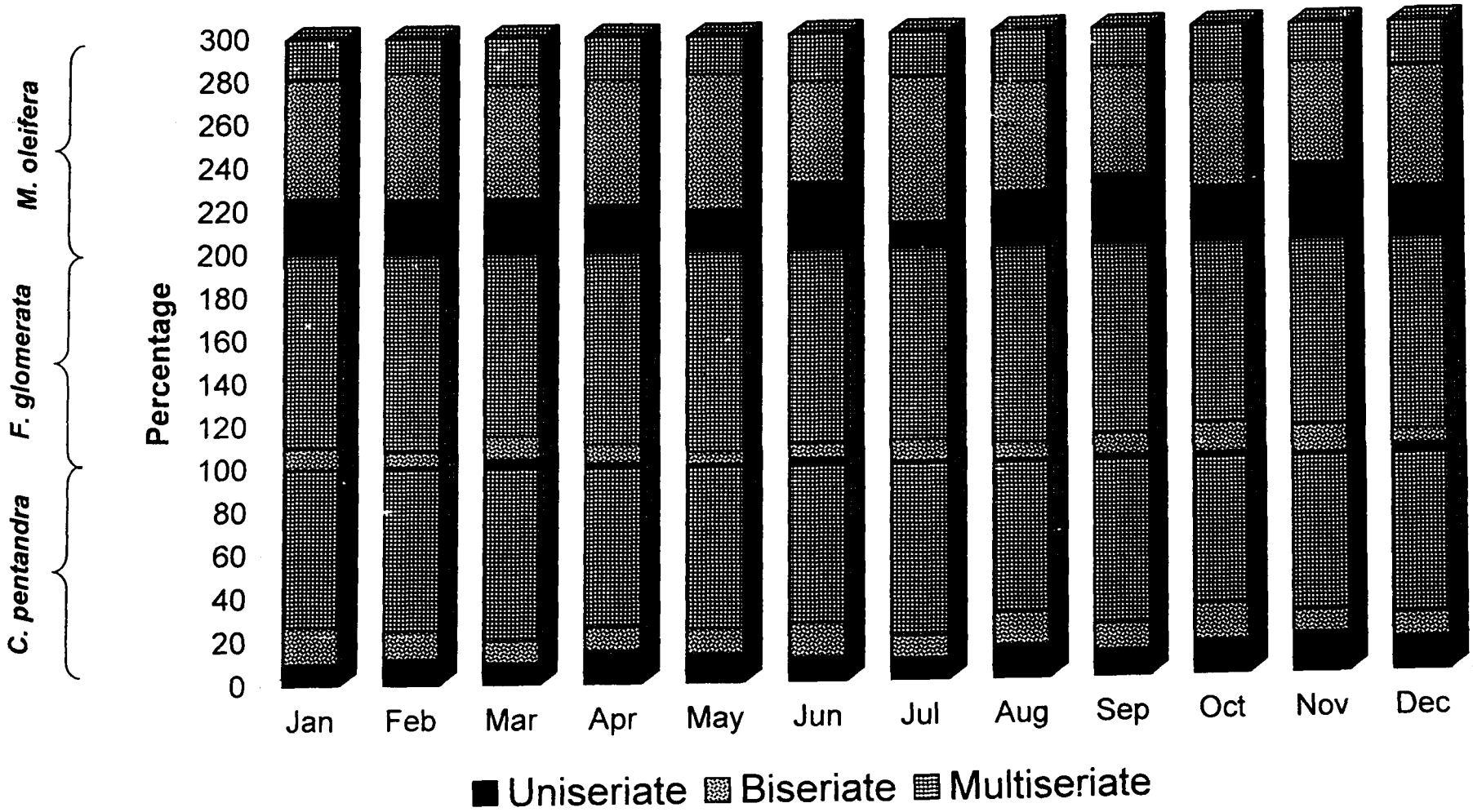


Figure-25: Percent rays in non-conducting phloem.

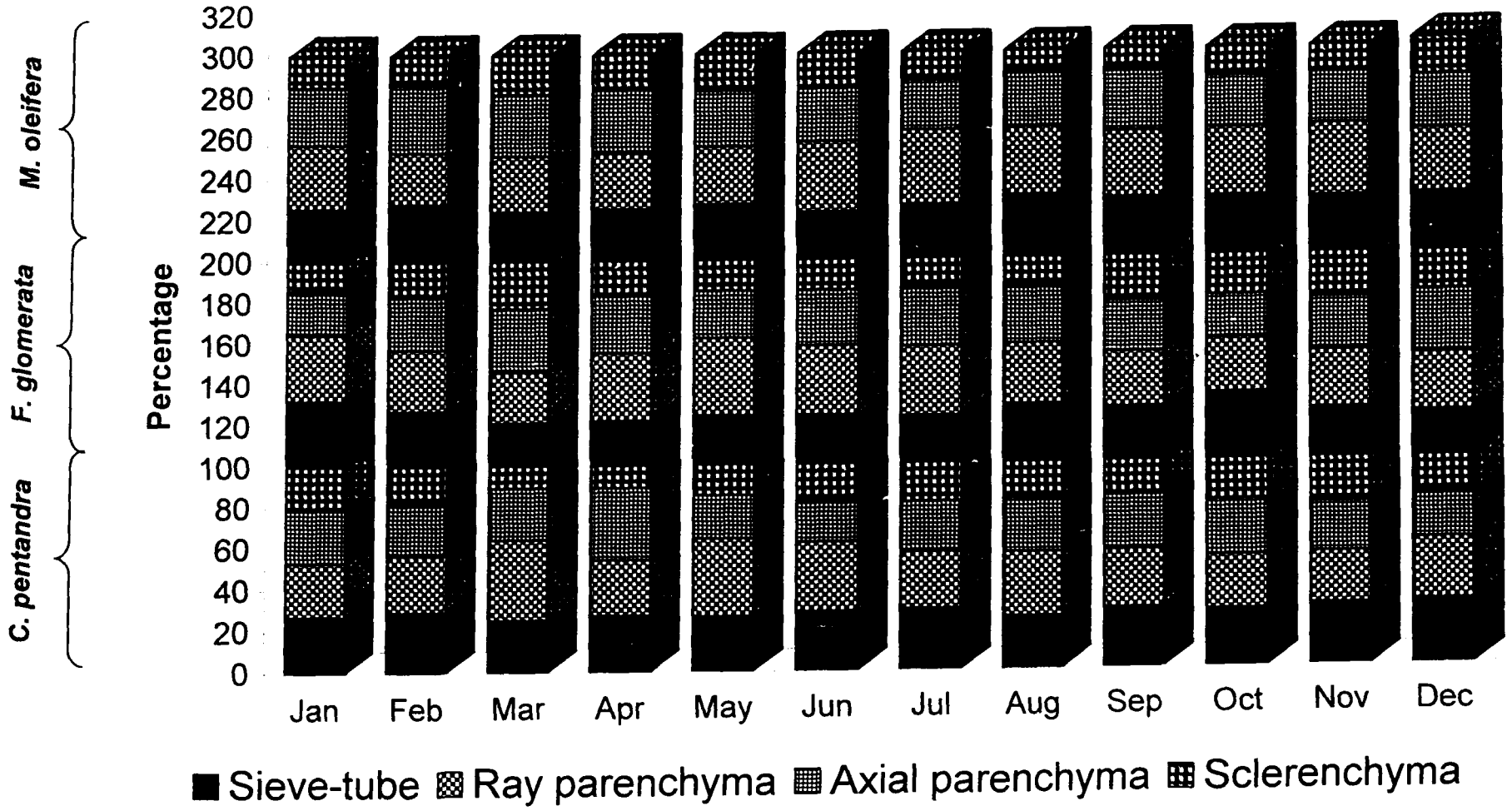


Figure-26: Percent transectional area in conducting phloem.

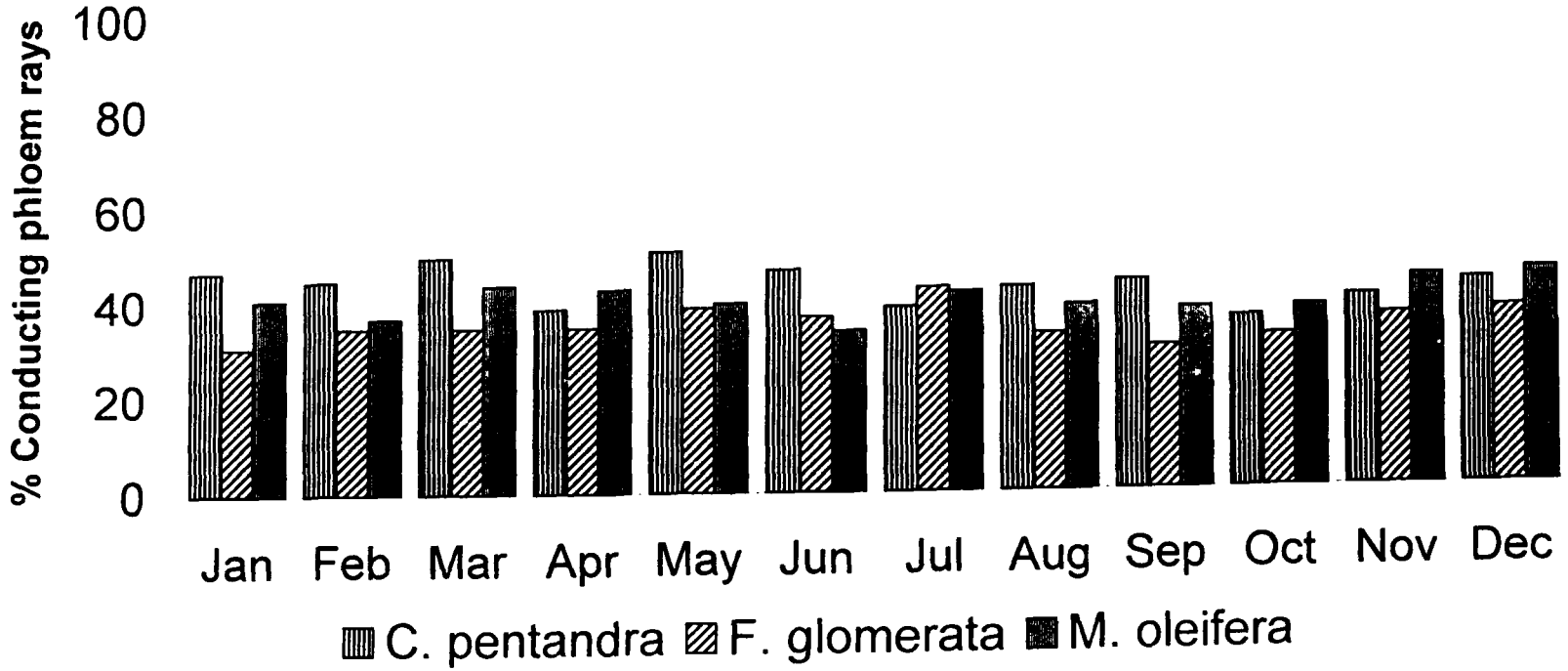


Figure-27: Percent tangential area (conducting phloem rays).

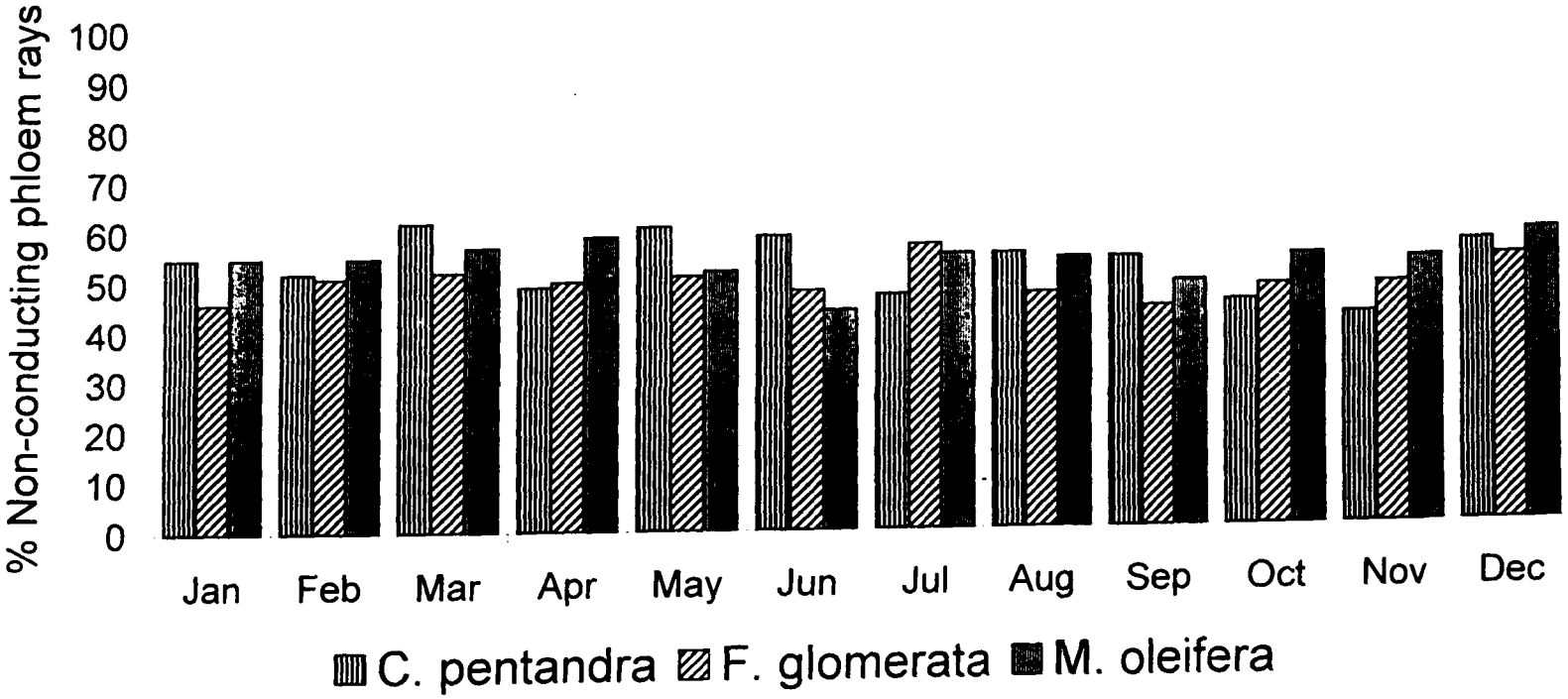


Figure-28: Percent tangential area (non-conducting phloem rays).

Periodicity of cambium:

In all the three species investigated, the vascular cambium experiences definite periods of activity and dormancy during a calendar year. During the active period the fusiform cambial cells are found relatively thin and having nearly smooth radial walls due to absence of thickened areas, alternating with the primary pit fields (Plates- I-B,E, III-C, IV-B,C, V-C). Sometimes the radial wall show beaded structure during the active period but it is not so prominent as in the inactive period. During the active period, the cambial zone, takes light stain due to the absence of coloured contents and loss of chromaticity of protoplasm. In the inactive period, the cambial zone is represented by a narrow zone of tangentially flattened cells and made up of 3 to 8 layers in *C. pentandra*, 4 to 9 layers in *F. glomerata* and 5 to 8 layers in *M. oleifera*. During the resting period, the radial walls of cambial cells are found to be comparatively thicker than that of active period. The radial walls show prominent beads during this period in the tangential view due to presence of alternately thickened areas and the deeply depressed primary pit fields, through which they communicate by plasmodesmata connections with the contiguous elements. Protoplasmic contents as well as the nucleus become relatively dense during the inactive period.

In all the three species, the vascular cambium, after experiencing a definite period of dormancy, undergo activation once in a year. The sign of activity appears in early May in *C. pentandra*, in mid January in *F. glomerata* and in early June in *M. oleifera*. The cells in the cambial zone undergo radial expansion in first week of May in *C. pentandra*, third week of January in *F. glomerata* and in first week of June in *M. oleifera*.

As a result of this enlargement the cambial zone swells up from 125 - 162 μm in *C. pentandra* 62 - 112 μm in *F. glomerata* and 62 – 125 μm in *M. oleifera*.

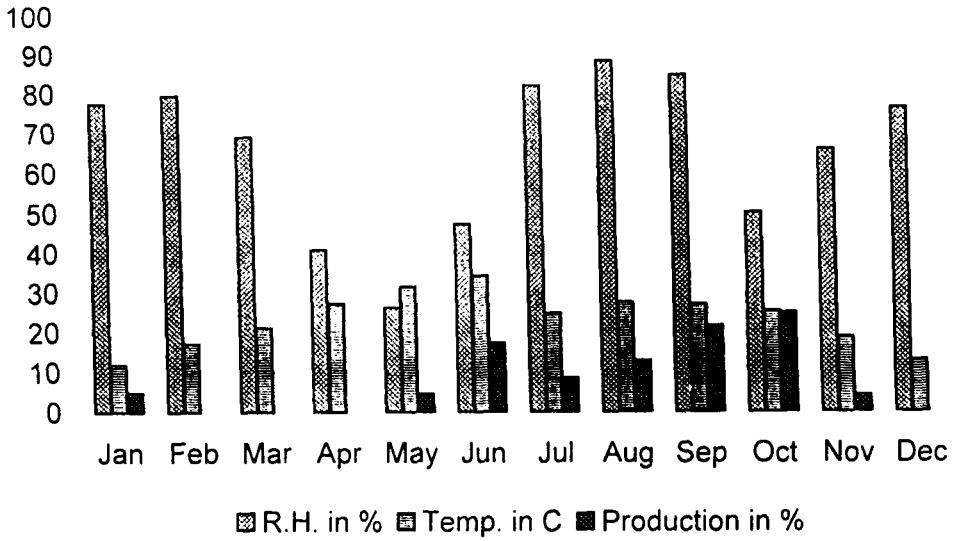
The cells start dividing in *C. pentandra* in mid May which causes an increase in layers of cells from 5-15. In *F. glomerata*, the cambial cell division stats, in late January increasing the number of cambial layers from 5-12 while in *M. oleifera* the cell division in cambium starts in mid June causing an increase in number of cambial layers from 5-11. In *C. pentandra,* the newly produced derivatives first differentiate into phloic elements in the month of May as a result of which about 140 μm of phloem is added to the plant axis. In *F. glomerata*, the newly produced derivatives differentiate first into phloic elements in the month of January adding about 90 μm phloem. In *M. oleifera*, the newly produced derivatives differentiate into phloic as well as xylem elements simultaneously in the month of June adding about 56 μm phloem and about 206 μm xylem to the plant axis.

Out of newly produced cambial derivatives, in *C. pentandra* the phloem production is observed in the month of May, June and July and about 150 μm precursor phloem forms in the month of January while xylem production is noticed from June to November of which the bulk is produced in September and October i.e. about 625 μm and 718 μm respectively in *C. pentandra.* In *F. glomerata*, the phloem production is observed in January, February and July while xylem production is observed from February to September of which the maximum is produced in September i.e. about 600 μm. In *M. oleifera*, the phloem production is observed in June, July, August, September and November, while xylem production is noticed

from June to October of which the bulk is produced in August and October i.e. about 562μm and 687μm respectively (Figs. 29-31).

The cambium becomes dormant during late November in *C. pentandra* and *M. oleifera* while in *F. glomerata* dormancy is attained in late September. Thus the cambium remains active about 7 months in *C. pentandra*, 9 months in *F. glomerata* and 6 months in *M. oleifera* (Fig. 32).

Thus, during the two calendar years 2003 and 2004 and the total amount of xylem produced varied from 1900 - 2000 μm with an average xylem production being 1950 μm in *C. pentandra* from 2000 – 2300 μm with an average of 2150 μm xylem being produced in *F. glomerata* and from 1500 - 1700 μm with an average of 1600 μm being produced in *M. oleifera*. Similarly the production of phloem varied from 750 - 800 μm, 250 -270 μm and 400 - 460 μm with an average phloem production being 775 μm, 260 μm and 430 μm in *C. pentandra*, *F. glomerata* and *M. oleifera* respectively.



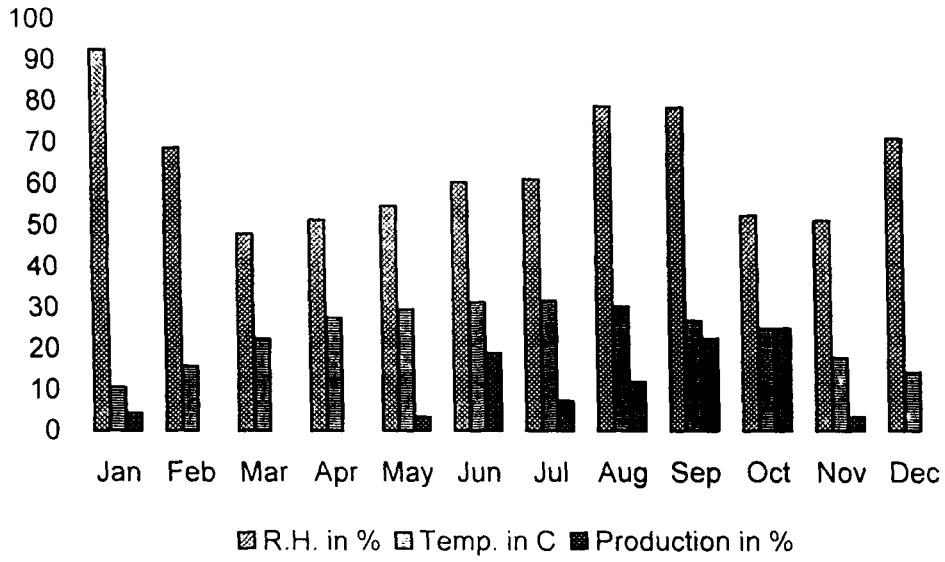
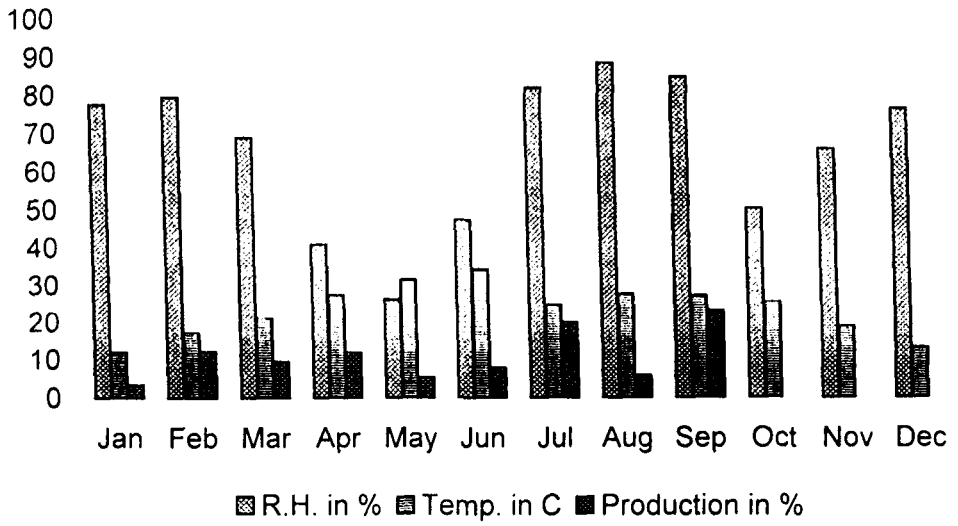


Fig. 29. Production of cambial derivatives in *C. pentandra*



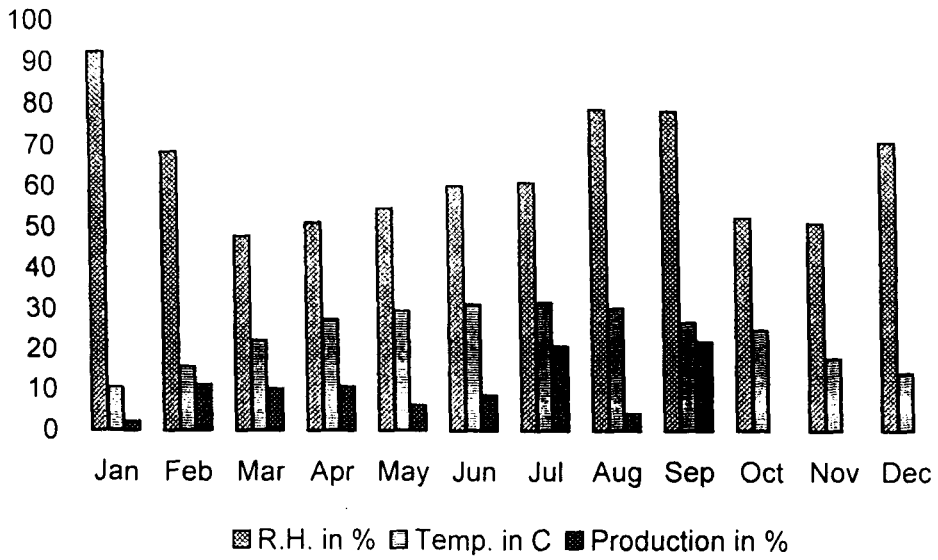
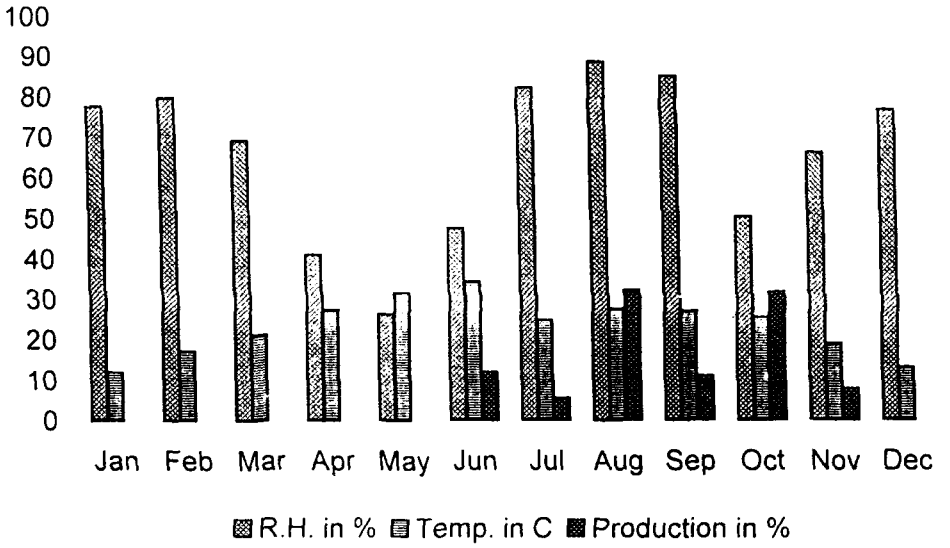


Fig. 30. Production of cambial derivatives in *F. glomerata*



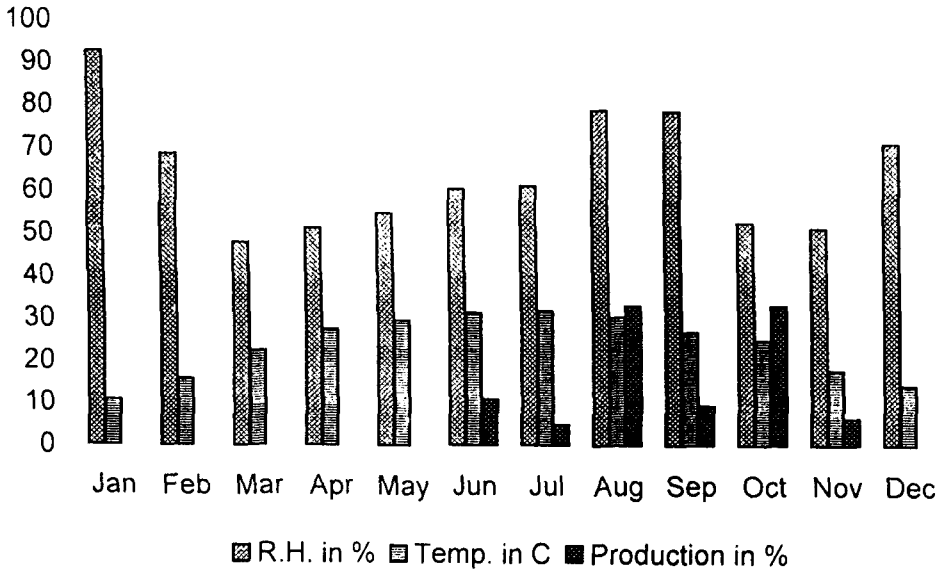
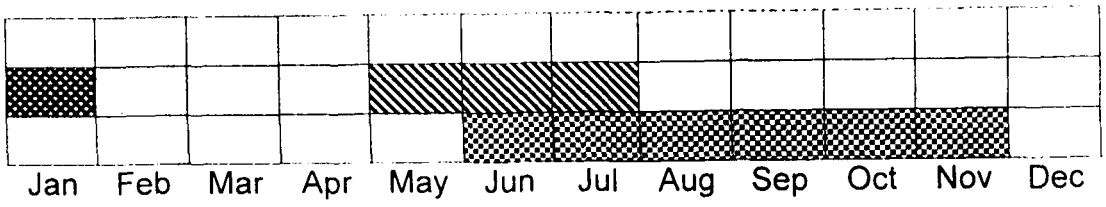
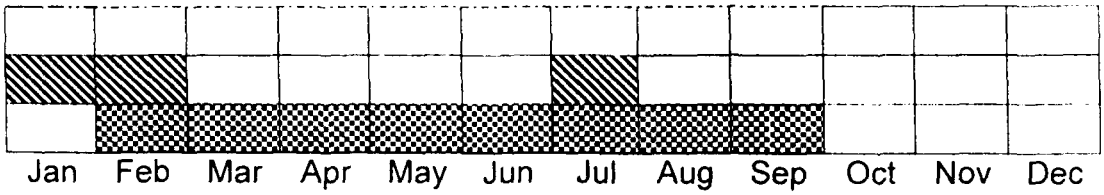


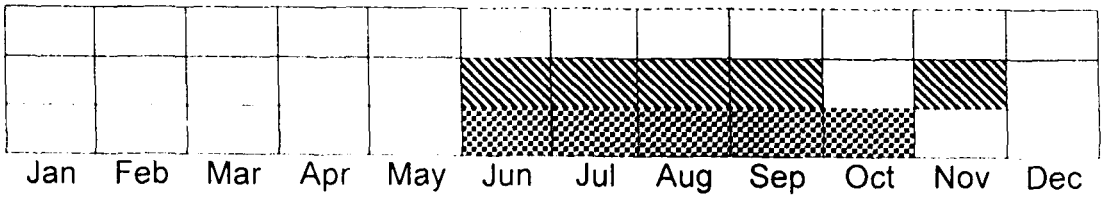
Fig. 31. Production of cambial derivatives in *M. oleifera*



C. pentandra



F. glomerata



M. oleifera

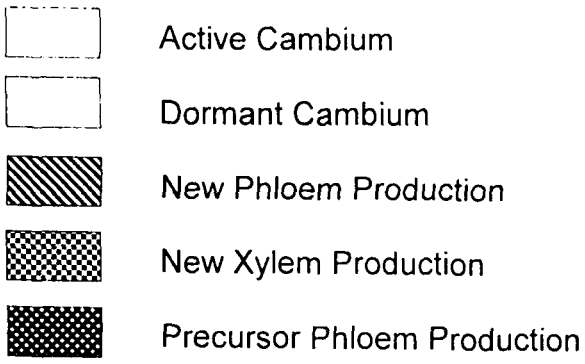


Fig.32

Longevity of phloem:

As aforesaid, the vascular cambium of *C. pentandra* becomes active in first week of May, *F. glomerata* in third week of January and *M. oleifera* in first week of June. But in *C. pentandra*, well before the commencement of cambial activity, a few layers of new phloem come into existence in the month of January. This part of phloem, the precursor type, appears to have developed from the outer derivatives of the cambium, which is produced at the inactivation of last growth season and remained in less differentiation or undifferentiated form. The precursor phloem which is produced in the month of January amounts to about 150 μm in *C. pentandra* and the current year phloem measures about 645 μm in depth which is produced in the month of May, June and July. The precursor phloem becomes non-functional in May when the current year phloem is produced. Thus the precursor phloem functions only for about 4 months. Out of the current year phloem i.e. 645 μm, only about 185 μm remains functional up to December i.e. for about 7 months and the rest goes non functional. The accumulation of callose on sieve pores as well as lateral walls of sieve elements renders them to go non-functional (Plates-XII-B, XIII-B, XIV-B).

In *F. glomerata*, the phloem production occurs twice in a year, the first addition being in January and February and the second addition in July. No precursor phloem formation occurs in this species. The total amount of phloem added during a calendar year is about 260 μm. In this species, a narrow strip of about 70 μm phloem produced in July remains active up to January showing longevity period of about 6 months and about 100 μm out of the total phloem produced in January remains

functional up to June when second addition of phloem takes place, thus showing longevity of about 5 months.

In *M. oleifera* phloem differentiation also occurs twice in a year, the first addition being in June, July, August, September and the second addition in November. In this species, the total amount of phloem added during a calendar year is about 430 μm. A strip of about 100 μm phloem produced in November remains active up to June. Thus showing longevity of about 7 months, and the phloem produced in June i.e. about 112μm remains active up to October for about 4 months.

Discussion

DISCUSSION

Vascular cambium:

Sanio (1863) happens to be the first botanist to recognize cambium as a lateral meristem. The term cambium owes its origin to Grew (1682). Its cellular make-up and nature has been elaborated by the German botanists of the past. Hartig, (1853) envisaged the cambial cylinder to be biseriate, the outer layer of the initials giving rise to phloem and the inner one to xylem. This concept of double initials was soon replaced by the concept of uniseriate cambial initials (Sanio, 1873; Mischke, 1890; Schoute, 1902). De-Bary (1884) considered the cambium to consist of a single initial layer and the layers of tissue mother cells both on the wood side as well as on the bast side, the initials being responsible for the production of the mother cells. This view was advocated mainly by Bailey (1923) and Bannan (1955, 1962, 1968) has been adopted by most subsequent workers (Esau, 1948; Evert, 1963a; Evert and Deshpande, 1970; Kozlowski, 1971; Steeves and Sussex, 1972; Ghouse and Yunus, 1973; Butterfield, 1975; Yunus *et al.* 1978; Khan *et al.*, 1983; Iqbal and Ghouse, 1985a).

It is generalized opinion that the vascular cambium originates in the fascicular region first and later extends tangentially in interfascicular regions (Esau 1965). However, Fahn *et al.* (1972) have reported the vascular cambium to develop first in interfascicular region rather than in the fascicular ones in *Ricinus communis*. But the observations recorded in the present study regarding formation of cambium

goes against the findings of Fahn *et al.* (1972) and support the commonly held view as noted in certain earlier cases (Esau, 1939, 1942, 1943, 1965; Grunkel and Whitmore, 1946; Sterling, 1946, 1947; Parke, 1963; Cumbie, 1967; Soh, 1972; Ghouse *et al.* 1972; Ghouse and Yunus, 1973; Butterfield, 1975; Khan, 1977; Khan, 2001) that the procambial cell experiences repeated periclinal division in order to produce rows of radially aligned elements before they transform into true cambial initials. In the present study also similar observations have been recorded in all the three species investigated. The appearance of ray initials has been taken as a sole criterion to indicate cambium formation in the present study following the concept of Catesson (1964).

Vascular cambium in general is made up of elongated fusiform initials and roughly isodiametric ray initials. On the basis of arrangement of these initials, two basic types of cambial structures have been recognized. In one of them the fusiform initials occur in horizontal tiers with the end of cells appearing approximately at the same level in a given tier and in the other, the end walls of the adjacent initials overlap to a considerable extend. The former is called as storied cambium, while the other non-storied (Bailey 1923). On the basis of observations on a number of vascular plants, belonging to different natural orders, Bailey (1923) conceived that storied structure of cambium as phylogenetically advanced (Eames and Mac Daniels, 1947; Metcalfe and Chalk, 1950; Barghoorn, 1964; Esau, 1965, 1977; Fahn, 1974, 1982; Ghouse and Yunus, 1974a; Siddiqui, 1983; Khan, 2001). In the presently investigated species, arrangement of cambial initials depicts a clear semi-storied structure in *C. pentandra*, non-storied in *F. glomerata* and *M. oleifera.* The presently investigated *C.*

pentandra may also be said as phylogenetically advanced taxa as they depict a semi-stratified structure of the cambium (Siddiqui, 1983). The non-storied structure of cambium has been reported earlier by several workers Khan (1977), Hashmi (1977), Iqbal (1979), Khan (1980), Khan (1984), Ajmal (1985), Kafeel (1986), Khan (2001) and Mahmood (2001).

Bailey (1923) measured cambial initials of a wide variety of tropical as well as temperate trees and concluded that the fusiform initial are generally shorter in stratified category. Bailey (1923) further found that the fusiform initials vary in length from 460-4400 μm showing non-stratified cambium. The observations regarding this aspect indicate that in the presently investigated species, the length of fusiform initials ranges from 212.50-712.50 μm in *C. pentandra*, having a significantly higher range as compared to the other two species, which is contrary to the findings of Bailey (1923). Length of fusiform initial ranges from 150.00-612.50 in *F. glomerata* and from 125.00-437.50 in *M. oleifera* which goes in agreement with results of some earlier workers like Ghouse and Iqbal (1975) in some arid zone species of *Acacia* and *Prosopis*, Ghouse and Hashmi (1977) in some Indian tropical trees, Ghouse *et al.*, (1980) in some Verbenaceae, Khan (1980) in some Myrtaceae, Bartwal *et al.* (1983) in some Indian fruit trees, Cumbie (1983) in *Bvocconia vulcanica,* Khan (2001) in *Jacaranda mimosaefolia*, *Pterospermum acerifolium* and *Terminalia arjuna* who have found fusiform initial length to fall shorter than Bailey's (1923) reported limit for non-storied cambium.

Among the three species investigated in the present study *M. oleifera* is found to possess comparatively short

fusiform initials while *C. pentandra* the longest and *F. glomerata* falling in between these two. If size of fusiform initials is taken as indication of phylogenetic advancement, obviously *M. oleifera* appears to be the most evolved form among the presently investigated species. The structural changes that the cambium undergoes during different phases have been elaborated by several earlier workers (Eames and Mac Daniels, 1947; Evert, 1963a; Esau, 1965; Srivastava and O'Brein, 1966; Mahmood, 1968, 1971; Robards and Kidwai, 1969; Murmanis, 1970, 1971 Yunus, 1976; Hashmi, 1977; Khan, 1977; Iqbal, 1979; Khan, 1980; Dave and Rao, 1982a; Siddiqui, 1983; Ajmal, 1985; Ajmal *et al.*, 1986b; Kafeel, 1986; Rao and Dave, 1986; Iqbal, 1989; Venugopal and Krishnamurthy, 1989, 1994; Khan 2001 and Mahmood, 2001).

The radial walls of fusiform initials have been reported to be usually thicker than tangential walls, especially during dormancy and the primary pit fields appear deeply depressed in tangential longitudinal view giving a beaded look to the radial walls Iqbal (1990). Similar observations have been made in present study too in all the three species investigated.

The cambial initials have been reported to undergo anticlinal and periclinal divisions periodically (Bailey, 1919, 1923; Eames and Mac Daniels, 1947; Bannan, 1956; Esau, 1965; Fahn, 1974; Ghouse and Yunus, 1973; Rao and Dave, 1986; Han and Soh; 1991) Anticlinal division add to the cambial population while the periclinal ones increase the number of cambial derivatives emanating new phloem and xylem elements. Bailey (1923) recognized two fundamental types of anticlinal divisions in the different vascular species investigated by him. In one type, the anticlinal division occurs

in a radial longitudinal plane and in the other pseudotransverse wall formation takes place running askew intersecting the two radial walls at two different levels (Philipson and Ward, 1965; Philipson *et al.*, 1971; Khan, 1977; Iqbal, 1979; Khan, 1980; Khan and Siddiqui, 1980, 1983; Khan *et al.*, 1980, 1982; Siddiqui, 1983; Zagorska-Marek, 1984; Ajmal, 1985; Kafeel, 1986; Han and Soh, 1991; Venugopal and Krishnamurthy, 1994; Khan, 2001 and Mahmood, 2001).

In the present study the anticlinal divisions in the cambial initials have been noted to be pseudotransverse, as it has been found in majority forms having non storied cambium (Bailey, 1923; Esau, 1965; Fahn, 1974; Iqbal, 1989; Khan, 2001 and Mahmood, 2001). The pseudotransverse wall formation observed in present study varies in length from short to long in all the species investigated. Sometimes the dividing wall almost extending from one end of the cell to the other, as it has been reported earlier by Hashmi (1977) in *Delonix regia,* Khan (1977) in *Psidium guajava,* Iqbal (1979) in some arid zone species, Khan (1980) is some Myrtaceae and Siddiqui (1983) in some Moraceae.

The development of ray initials has been worked out in detail by Barghoorn (1940a, b, 1941a, b), Braun (1955) in conifers and dicotyledons, Bannan (1950, 1951, 1953, 1956), Evert (1959, 1961), Cumbie (1963, 1967, 1969a, b), Srivastava (1963a, b), Cheadle and Esau (1964), Ghouse and Yunus (1973), Ghouse and Iqbal (1977a, Hashmi (1977), Khan (1977), Siddiqui (1983), Ajmal (1985), Kafeel (1986), Iqbal and Ghouse (1987), Ajmal and Iqbal (1992). The ray initials may arise primarily as a single cell which is cut at the ends as

terminal segment (Bannan, 1951, 1956; Braun, 1955; Khan, 1977; Khan, 1980; Siddiqui, 1983; Ajmal, 1985; Kafeel, 1986; Khan, 2001 and Mahmood, 2001) or as lateral segments (Evert, 1959, 1961, 1963a; Ghouse and Yunus, 1973; Ghouse and Iqbal, 1977a; Hashmi, 1977; Khan, 1977; Khan, 1980; Siddiqui, 1983; Khan, 2001 and Mahmood, 2001) or they may arise by transverse segmentation of fusiform initials (Whalley, 1950; Bannan, 1951; Ghouse and Yunus, 1973; Hashmi, 1977; Khan, 1977; Khan, 1980; Siddiqui, 1983; Khan, 2001). In the presently investigated species, the first two types of ray development are found to be more frequent than the last type. Once the ray initials get established, they continue to undergo multiplication resulting in expansion of rays in height and width (Barghoorn, 1941b; Braun, 1955; Evert, 1961; 1963a; Ghouse and Yunus, 1973; Ghouse and Iqbal, 1977a; Hashmi, 1977; Khan, 1977; Khan, 1980; Khan *et al.*, 1983; Siddiqui, 1983; Ajmal, 1985; Kafeel, 1986). Contrary to above, some of long and broad rays get splitted up into smaller units by intrusion of adjacent fusiform initials in all the three species investigated as it has been reported by (Barghoorn 1940a,b; Esau, 1965, 1977; Evert, 1961; Ghouse and Iqbal, 1977a, Khan, 1977; Bartwal *et al.*, 1983; Khan *et al.*, 1983; Siddiqui, 1983; Rao, 1988; Iqbal, 1989).

The ray initials form an integral part of the cambial cylinder in all the three species investigated. The relative proportion of ray initials to that of fusiform initials has been found to vary from species to species. A maximum of 44% has been observed in *C. pentandra* and minimum 33% in *M. oleifera* while in *F. glomerata* the ray initials constitute about 37% of tangential area of cambial cylinder in adult trees. In a similar study, Khan (1977) in *Psidium guajava* has found ray

initials to reoccupy 30-37% and in several other tropical species worked out by group of Indian workers, the ray initials have been shown to vary from 20-40% depending on genetic constitution as well as age and size of the tree (Ghouse and Yunus, 1973, 1974a, b, 1976a; Ghouse and Iqbal, 1975, 1977a; Ghouse and Hashmi, 1977; Ghouse *et al.*, 1975a, b, 1976a; Kafeel, 1986; Khan *et al.* 1979a; Khan, 1980; Siddiqui, 1983, Ajmal, 1985 and Khan, 2001). However, the earlier findings on this aspect of cambial anatomy do not agree with the present findings since they show that fusiform initials constitute more than 90% of cambial cylinder (Bailey, 1923; Wilson, 1963, 1964; Kozlowski 1971; Butterfield, 1972; Margaris and Popadogianni, 1977).

It is evident from the present studies that the fusiform cambial initial experience considerable length variation as the tree grows in thickness in all the species investigated in present research, the length of fusiform initials shows an increasing trends from top to base downwards in *C. pentandra* which coincides with the report of Cumbie (1969a) and Khan (1980); Khan, (2001), Mahmood, (2001). In *F. glomerata* a consistent increase from the tree apex to basewards but after having attained a maximum it tends to decline further towards the base which goes in agreement with result of Ghouse and Iqbal, 1977a; Khan *et al.*, 1983; Ajmal, 1985; Mahmood, 2001. While in *M. oleifera* the length exhibits increasing tendency with the advancing age and soon gets stabilized near the base which coincides with the report of Bailey, 1923, Bosshard, 1951; Hejnowicz and Hejnowicz, 1958; Evert, 1961, 1963a, Bannan, 1962; Ghouse and Yunus, 1973; Ghouse and Hashmi, 1980a.

In the present study the observations on ray initial reveal that in *M. oleifera* the size of ray initial increase with increase in the girth of stem axis Khan (2001). In *C. pentandra* and *F. glomerata* their size first exhibits an increasing trend which is followed by a declining tendency. Contrary to above findings the ray initial do not evince any appreciable change in their dimension in relation to age of the axis (Khan, 1980; Siddiqui, 1983; Ajmal, 1985). However, they undergo multiplication to become multiseriate in older axis (Bailey, 1923; Braun, 1955; Ghouse and Yunus, 1973; Ghouse and Iqbal, 1977a, Khan, 1977, Iqbal, 1979; Khan, 1980; Khan *et al.*, 1981, Khan *et al.*, 1983; Siddiqui, 1983; Ajmal, 1985; Ajmal *et al.*, 1986a; Kafeel, 1986; Iqbal and Ghouse, 1987, Ajmal Iqbal 1992; Khan, 2001 and Mahmood, 2001).

As a consequence of developmental changes in cambial zone, relative proportion of fusiform and ray initials also varies with age of stem axis. The ray initials occupy 32-46% in *C. pentandra*, 31-41% in *F. glomerata* and 42-55% in *M. oleifera* of the total tangential area of the cambial cylinder. An increase in the proportion of ray initial from the apex down to the base of the tree has been reported in many Indian species such as *Dalbergia sissoo* (Ghouse and Yunus, 1973), *Psidium guajava* (Khan, 1977), *Acacia nilotica* (Iqbal, 1979), *Polyalthia longifolia* (Ghouse and Hashmi, 1980a), *Callistemon citrinus*, *Eucalyptus maculata* and *Eugenia jambolana*, (Khan, 1980), *Bauhinia parviflora* (Khan *et al.*, 1981) *Citrus sinensis* (Khan *et al.*, 1983), *Ficus infectoria* and *Ficus religiosa* (Siddiqui, 1983), *Ficus rumphi* and *Sterbulus asper* (Ajmal, 1985), *Jacaranda mimosaefolia, Pterospermum acerifolium* and *Terminalia arjuna* (Khan, 2001) *Alstonia scholaris, Emblica officinalis* and *Putranjiva roxburghii* (Mahmood, 2001).

As far as dimensional variations in relation to different seasonal changes are concerned it has been noted that length and width average of fusiform initials as well as magnitude of ray initials vary to some extent depending on the time of development of new cambial initials and the period of their growth. Similarly, frequency of uniseriate and short cambial rays has been found higher in active period than in the inactive phase of the cambium. Earlier workers have also reported such changes both in size and magnitude of different types of cambial initials in tropical trees (Yunus, 1976; Hashmi, 1977; Khan, 1977, Iqbal, 1979; Khan, 1980; Dave and Rao, 1982a; Siddiqui, 1983; Ajmal, 1985; Kafeel, 1986). The ray initials multiply considerably to become multiseriate in older axis in all the three investigated species as has been reported by earlier workers (Ghouse and Yunus, 1973; Ghouse and Iqbal, 1977a; Khan, 1977; Iqbal, 1979; Khan, 1980; Siddiqui, 1983; Khan, 2001).

Secondary xylem:

Secondary xylem being a complex tissue comprises of various types of elements viz., tracheids, vessel elements, fibres, parenchyma cells, ray cells and sometimes secretary cells. The occurrence and arrangement of these elements vary in different groups of plants. The quantitative difference in number of cells as well as in the size of the elements that exists between the species of a single genus makes it possible to identify the plant by its secondary xylem alone. The secondary xylem of dicotyledons is more complex than that of gymnosperms. Dicotyledonous wood comprises of elements that vary in size, shape, type and arrangement. In the secondary xylem of *Quercus* e.g., vessel elements, tracheids, fibre tracheids, libriform fibres, gelatinous fibres, wood parenchyma and rays of different sizes are found. However, there are some dicotyledonous trees in which the wood is comprised of a smaller number of element types. For instance, in many species of Juglandaceae, apart from vessel elements and parenchyma cells, only fibre-tracheids are found in the wood (Fahn, 1974).

The arrangement of vessel elements in the secondary xylem of dicotyledons is a characteristics feature and is frequently used in identification of species. When the vessel elements are more or less equal in diameter and uniformly distributed throughout the wood, the wood is termed as diffuse porous wood. Some examples of species with such wood are *Acer* spp., *Populus alba, Acacia cyanophylla, Olea europea* and *Eucalyptus* spp. (Fahn, 1974). *Dalbergia* spp. (Yunus, 1976), *Delonix regia, Mimusops elengi* and *Polyalthia longifolia* (Hashmi, 1977), *Acacia nilotica* and *Prosopis spicigera* (Iqbal,

1979), *Ficus infectoria* and *F. religiosa* (Siddiqui, 1983); *Ficus rumphii* and *Sterbulus asper* (Ajmal, 1985), *Bauhinia purpurea* and *B. variegata* (Kafeel, 1986). Several Myrtaceae members are found to have diffuse porous wood such as some species of *Eucalyptus* (Dadswell, 1972), *Psidium guajava* (Khan, 1977), *Callistemon citrinus, Eucalyptus maculata* and *Eugenia jambolana* (Khan, 1980); twelve species of *Eucalyptus* (Khan *et al.*, 1980); *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna* (Khan, 2001); *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii* (Mahmood, 2001). In the presently investigated species, the wood is found to be diffuse porous. The vessel elements may be solitary or may form clusters (Fahn, 1982). The vessel elements are found solitary and in short radial multiples of 2-12 in *C. pentandra*, 2-6 in *F. glomerata* and 2-7 in *M. oleifera*. More or less similar findings have been reported earlier by (Yunus, 1976; Hashmi, 1977; Khan, 1977; Khan, 1980; Siddiqui, 1983; Ajmal, 1985; Kafeel, 1986; Khan, 2001; Mahmood, 2001; Banerjee *et al.*, 2004).

In different dicotyledonous species, the amount of axial parenchyma shows wide variations. In some species, there is very little axial parenchyma or it may be totally absent while in others, it constitutes a sufficiently large portion of the wood. Apart from the variations in the amount of axial parenchyma, their mode of distribution also varies in secondary xylem in different species. The mode of distribution of axial parenchyma is used as an important taxonomic character for the identification different species (Fahn, 1982). The axial parenchyma constitutes 32% in *C. pentandra*, 27% in *F. glomerata*, 31% in *M. oleifera*.

Sufficient work has been done on variations in size of xylem fibres of various gymnosperms and dicotyledons (Bissel and Dadswell, 1949; Morey *et al.* 1950; Scaramuzzi, 1955; Bailey, 1957; Hejnowicz and Hejnowicz, 1958; Dinwoodie, 1961; Carlquist, 1962; Fahn and Leshem, 1963; Kedarnath *et al.*, 1963; Parameswaran, 1964; Burley, 1969; Dadswell, 1972; Sundersivarao *et al.*, 1973; Purkayastha *et al.*, 1974; Khan, 1977; Sundersivarao and Nazma, 1977; Khan *et al.*, 1979b, c; Khan, 1980; Iqbal and Ghouse, 1983; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Kafeel, 1986; Ajmal and Iqbal, 1992; Castro and Ademir, 1992; Lim and Soh, 1997; Jorge *et al.*, 2000; Khan, 2001; Mahmood, 2001). In the presently investigated species *M. oleifera* is found to have short xylem fibres while *C. pentandra* the longest and *F. glomerata* falling in between these two.

Observations on xylem fibres have shown that they experience apical intrusive growth to the extent of 5.013, 4.151 and 2.582 times over the size of their mother initials in *C. pentandra, F. glomerata* and *M. oleifera* respectively. Similarly, Khan *et al.*, 1979c have reported xylem fibres in *Eucalyptus camaldulensis* and *E. papauana* grow to the extent of 1.54-1.8 times over their mother initials. Khan *et al.*, (1979b) again have shown that in some Verbenaceae, the extent of apical growth in xylem fibres varies from 1.8-5.4 times over their mother initials in different species. Khan, (1980) has recorded apical intrusive growth to the extent of 1.4-1.6 times over the size of their mother initials in some Myrtaceae members. Siddiqui, (1983) has reported apical intrusive growth to extent of 3.54 and 4.40 times over size of mother initials in some Moraceae. Khan, (1984) has reported that xylem fibres undergo apical intrusive growth 5.50-6.33

times over the size of their mother initials in *Bombax malabaricum*. But Cheadle, (1937) has found that in some woody Liliaceae the xylem fibres grow 15-40 times over the size of their mother initials while Anand *et al.*, (1978) reported xylem fibres in *Dalbergia sissoo* to grow 8-9 times longer than their mother initials. However, the present findings go in conformity with observations of Khan *et al.*, (1979b,c) and Siddiqui, (1983).

During the course of present investigation, the average length of vessel elements show an increasing trend with increasing girths of the axis in *C. pentandra*. Increasing trend in vessel length from top towards the base has also been reported by Siddiqui, (1983) in *Ficus religiosa*, Carlquist, (1989) in new world species of *Ephedra*, Castro and Ademir, (1992) in *Sacoglottis guianesis* and *Andira parviflora* and by Han and Soh, (1993) in *Populus eurameriana*, Khan 2001 in *Jacaranda mimosaefolia* and Mahmood, 2001 in *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii*. In *F. glomerata* and *M. oleifera* average length of vessel elements initially increase with age and after experiencing a slight decline again there is gain in length with advancing age as has been reported by Khan, 2001 in *Pterospermum acerifolium*. Contrary to this Ajmal, (1985) reported vessel element length to increase from apex towards the base but after having attained maximum in basal region, it declines in *Ficus rumphii*. On the other hand, Siddiqui, (1983) has reported vessel length to show a gradual decrease up to base in *Ficus infectoria*, Iqbal and Ghouse, (1977a) in *Prosopis spicigera*, Khan (1980) in *Eucalyptus maculata* observed the length of vessel elements initially increases and tends to remain constant for some distance and finally declines near the ground level. Rao *et al.*,

1973; Khan and Ghouse, 1977; Khan *et al.*, 1980 has also shown the variations in size of vessel elements.

The radial diameter of vessels gradually increase from top to basewards and shows a declining tendency at the extreme basal region in *C. pentandra* & *F. glomerata* as has been reported by Ajmal (1985); Khan (2001) and Mahmood (2001). In *M. oleifera* radial diameter first undergoes expansion with increasing age of the axis which is followed by a constancy near the basal region as has been reported by Khan, (1980) in some Myrtaceae, Siddiqui, (1983) in *Ficus infectoria* and Ajmal, (1985) in *Sterbulus asper*; Khan 2001 in *Pterospermum acerifolium* and Mahmood, 2001 in *Alstonia scholaris*.

As far as tangential diameter of vessel is concerned, it shows a consistent increase in tangential widening in vessels from apex towards base and after attaining a maximum is followed by a decline in *C. pentandra* and *F. glomerata* as it has been reported earlier by Ajmal (1985) while in *M. oleifera* tangential diameter record a continuous increase with growing girth corresponding to increasing age of tree axis as it happens in *Prosopis spicegera* (Iqbal and Ghouse, 1977a).

During the course of present investigation it has been observed that xylem in young shoots consists of narrow lumened vessels (small) proportionally higher in number in all the three species investigated. As the axis grows older, the number of large type vessels shows an increasing tendency. More or less a similar trend has been reported by earlier workers (Khan, 1977; Khan, 1980; Khan, 1984; Khan, 2001 and Mahmood, 2001). A continuous increase in vessel area from top to basewards has been observed in the presently

investigated species as it has also been reported in several other species (Khan, 1977; Khan, 1980; Khan, 1984; Khan, 2001 and Mahmood, 2001). An entirely different situation, a higher vessel proportion in young shoots than in old stem has been reported by Ollinnmaa (1955), and Bhat and Karkkainen (1980).

The axial parenchyma shows an inconsistent behaviour from top towards the base in the species investigated as has been reported by Khan, 2001. Contrary to this, axial parenchyma showing decreasing tendency from top towards base has been reported by Ajmal (1985) in *Ficus rumphii* and *Sterbulus asper*. Contrary to this some other workers have reported axial parenchyma to increase with increasing age of axis Khan (1977), Iqbal (1979), Khan (1980).

As far as dimensional variation of vessels, fibres, ray and axial parenchyma in relation to different weather conditions is concerned, they do not exhibit any considerable change in all the species investigated. Similar trend has been reported by Khan (1977), Khan (1980), Siddiqui (1983), Khan (1984), Ajmal (1985), Khan (2001) and Mahmood (2001).

Secondary phloem:

As compared to secondary xylem of the dicotyledons, the secondary phloem has relatively complicated structure. However, the principal arrangement of cells in the secondary phloem parallels that of secondary xylem. The secondary phloem consists of two well-defined system of cell viz. axial or vertical and ray or horizontal system. The cells of the axial systems are derived from fusiform initials of the cambium while the rays system develops from ray initials. The axial system is composed of sieve tube members accompanied by one or more companion cells axial parenchyma fibres, and sclereids and occasionally laticifers and roughly isodiametric ray cells in the horizontal system. (Esau, 1965) Fibres and sclereids also develop in ray system (Khan *et al.*, 1976). Like other dicotyledonous species (Ghouse *et al.*, 1979), in the presently investigated species also, the cell arrangement has been noted to exhibit a great deal of diversity in the different species. In *C. pentandra*, sclerenchymatous fibres forming fascicles of varying dimensions which are arranged in tangential bands forming concentric order. Frequency of occurrence of sclerenchymatous fibres is significantly higher in towards the periphery of bark. In *F. glomerata*, sclerenchymatous fibres with sclerotic parenchyma having thin secondary lignified walls abundant in the peripheral part of bark occasionally they are also found in the partly obliterated non-conducting phloem region. In *M. oleifera* sclerenchymatous fibres solitary and in small groups of 2-3 at the periphery of the conducting phloem and in towards the periphery of the non-conducting barks having completely crushed phloem. There are big fascicles of sclerenchyma of varying dimensions and frequency of such fascicles of

parenchyma appears to be increasing with the increase in age of the bark. Sufficient work has been done by a number of workers on the phloem fibres Holedeide (1951), Chattaway (1953, 1955a,b,c,d,e, 1959), Chang (1954a, b), Zahur (1959), Santos (1960), Bamber (1962), Esau (1964), Outer (1967), Ghouse and Sabir (1974), Ghouse and Yunus (1974c, 1975, 1976b), Ghouse *et al.*, 1975c, 1976b), Ghouse and Siddiqui, (1976a,b), Khan *et al.*, (1976, 1977, 1978), Ghouse and Iqbal (1977b), Ghouse and Jamal (1979), Khan and Khan (1983) and Siddiqui (1983), Olson and Carlquist (2001).

The sieve-tube members in all the species investigated, are found to be arranged in linear order i.e., end to end, forming long pathways. The end walls of the sieve-tube members are mostly oblique in *C. pentandra*, slightly oblique to transverse in *F. glomerata* and mostly transverse in *M. oleifera*. They possess simple sieve plates in all the species investigated. Thus the structure of sieve-tube members indicate that they are comparatively phylogenetically advanced like many other dicotyledons (Esau, 1965; Ghouse and Yunus, 1975; Yunus, 1976; Hashmi, 1977; Khan, 1977; Iqbal, 1979; Khan, 1980; Fahn, 1982; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Kafeel, 1986; Khan, 2001; Mahmood, 2001). The lateral walls of these elements are also found to have numerous sieve areas through which lateral communication is maintained with contiguous elements.

The sieve-tube members measured shorter than the fusiform initials in all the species presently investigated at it has been reported in *Pyrus malus* (Evert, 1963b), *Dalbergia* spp (Ghouse and Yunus, 1975), *Delonix regia, Mimusops elengi* and *Polyalthia longifolia* (Hashmi, 1977), *Psidium guajava*

(Khan, 1977), *Prosopis spicigera* (Iqbal and Ghouse, 1979), *Callistemon citrinus, Eucalyptus maculata* and *Eugenia jambolana* (Khan, 1980), *Ficus infectoria* and *F. religiosa* (Siddiqui, 1983), *Bombax malabaricum* (Khan, 1984), *Ficus rumphii* and *Sterbulus asper* (Ajmal, 1985), *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna,* (Khan, 2001), *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii* (Mahmood, 2001).

The secondary phloem in all the three species consists of two distinct zones differing in their structure and function viz., conducting and non-conducting. The conducting zone consists of active sieve-tube members, the axial and ray parenchyma and sclerenchyma, while in the non-conducting zone the sieve-tube members have been noticed to be completely absent or in a deformed state. The inactive sieve-tube members in all the investigated species have been found loaded with definitive callose on their end walls as well as on lateral walls. Sooner or later the shape of the sieve elements gets changed due to the pressure created by the expansion of the adjacent of axial and ray parenchyma cells. More or less a similar tendency of deformation of sieve elements has been reported in other dicotyledons by Cheadle and Esau (1964) in *Liriodendron*, Khan (1977) in *Psidium guajava*, Ghouse and Hashmi (1979a) in *Polyalthia longifolia* and (1980b) in *Delonix regia*, Khan (1980) in *Callistemon citrinus, Eucalyptus maculata* and *Eugenia jambolana,* Siddiqui (1983) in *Ficus infectoria* and *Ficus religiosa* and in Conifers (Abbe and Crafts, 1939) in conifers, Khan (2001) in *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna* and Mahmood (2001) in *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii*. The ray parenchyma cells of non-conducting zone

are comparatively larger in size than the in conducting zone, the ray cells do not proliferate to the extent of forming wide wedges resembling dilated rays as has been observed by earlier workers (Schneider, 1945, 1952, 1955; Chattaway, 1955d; Whitmore, 1962; Ghouse and Yunus, 1974c; Siddiqui, 1983; Khan, 2001 and Mahmood, 2001).

The average depth of conducting phloem is found to vary during a calendar year from 94-594 μm in *C. pentandra* 60-165 μm in *F. glomerata* and 88-288 μm in *M. oleifera*. These findings go with the general concept that the conducting phloem forms only a fraction of a millimeter (Holedeide, 1951; Lawton and Lawton, 1971; Lawton, 1972; Ghouse and Hashmi, 1976b; Yunus, 1976; Ahmed *et al.*, 1977; Khan, 1977; Ghouse and Hashmi, 1979a, 1980b; Khan, 1980; Siddiqui, 1983; Khan, 1984; Khan, 2001 and Mahmood, 2001). On the other hand Whitmore (1962) found the conducting phloem to be 5-6 mm thick in Dipterocarpaceae.

During different seasons the length and lumen size of sieve elements do not show any significant change in the presently investigated species. More or less similar situations have been found earlier by Munch (1943), Esau and Cheadle (1956), Evert, *et al.* (1969), Tucker and Evert (1969), Lawton (1972), Yunus (1976), Hashmi (1977), Khan (1977), Khan (1980), Siddiqui (1983), Khan (1984), Khan (2001) and Mahmood (2001).

Data collected on the area extent occupied by sieve-tube members in the conducting phloem have revealed that the presently investigated species possess 21-32% of sieve tube area in transverse plane and the values obtained are not in agreement with the hypothesis of either Crafts or Munch that

the active area in the bark amounts roughly to 20% (Crafts, 1931, 1933) or 66% (Munch, 1930) or even more (Canny, 1973). The results obtained in the present study as well as that of others (Geiger *et al.*, 1969; Evans *et al.*, 1970; Lawton and Canny, 1970; Lawton, 1972; Ghouse and Hashmi, 1976; Ghouse *et al.*, 1976b; Khan, 1977; Khan, 1980; Siddiqui, 1983; Khan, 1984; Khan, 2001 and Mahmood, 2001) have shown that the active area in the conducting phloem appears to be more or less species specific and therefore, agree with the plea to undertake a detailed study on the structure of phloem of the concerned species, as an essential prelude to any physiological investigation concerned with translocation process.

The average length of the sieve-tube members shows a gradual increase with increase in stem circumference in *C. pentandra* and *M. oleifera* which goes in agreement with the findings of Khan (1977) in *Psidium guajava*, Ajmal (1985) in *Sterbulus asper* and Trockenbrondth (1994) in Oak, Khan (2001) *Jacaranda mimosaefolia, Terminalia arjuna*, Mahmood (2001) *Alstonia scholaris.* In *F. glomerata*, the average length of sieve-tube members increase with increasing age of the trunk, followed by a decline in the basal region. The same has been reported by Yunus (1976), Hashmi, (1977), Iqbal and Ghouse (1977b), Iqbal (1979), Khan (1980), Ajmal (1985), Kafeel (1986) Ajmal and Iqbal (1992) and Mahmood (2001). On the other hand Khan (1984) has reported in *Bombax malabaricum*, length average of sieve tube members to increase gradually from younger to older trunks till it reaches maximum and then tends to remain constant after a slight decline. Contrary to the above findings the length of sieve-tube members first increases with the age and after declining

for a distance, again increase near the base has been observed by Siddiqui (1983) in *Ficus infectoria* and *F. religiosa*. Studies on the lumen size of sieve-tube members of investigated species have revealed that tangential and radial diameter experience an increase with increasing girth of a stem axis in the beginning in all the presently investigated species viz. *C. pentandra F. glomerata* and *M. oleifera* as it has been found by several earlier workers like Yunus (1976), Hashmi (1977), Iqbal and Ghouse (1977b), Khan (1977), Iqbal (1979), Khan (1980), Siddiqui (1983), khan (1984), Ajmal (1985), Kafeel (1986).

Later lumen size in all the species investigated gets stabilized. *F. glomerata* and *M. oleifera* show stability with further increase in age which is wide contrary to the finding of Khan, 2001 in *Jacaranda mimosaefolia, Pterospermum acerifolium*. However in *C. pentandra* stability with the advancing stage of shoot axis is followed by declining tendency of the lumen size of sieve-tube members if happens in *Ficus rumphii* (Ajmal, 1985), contrary to this in *Terminalia arjuna* (Khan, 2001) after suffering a slight decline radial and tangential diameters exhibits an enlarging tendency.

The length of phloem fibres has been found to increase from top to the base downwards i.e., the length at top is less as compared to length at base in all the three species investigated. This goes in agreement with the findings of Khan (1984) in *Bombax malabaricum*, Ajmal (1985) in *Sterbulus asper* and Trockenbrondth (1994) in Oak and Popular species, Khan (2001), *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna,* Mahmood (2001), *Emblica officinalis, Putranjiva roxburghii*. Contrary to this an initial

increase in length of phloem fibres reaching a maximum and then a decline has been reported by Iqbal and Ghouse (1983) in *Acacia nilotica* and *Prosopis spicigera* Ajmal and Iqbal (1992) in *Ficus rumphii*. Width measurements of fibres have shown no specific trend in variation vis-à-vis age of the axis ash have reported by Khan (2001) and Mahmood (2001). However, recently, Quilho *et al.* (2000) has reported a gradual increase in fibre width from top towards the base of the axis. The length and width measurements of phloem fibres during different seasons did not show any significant change as has also been reported by (Khan, 1977; Khan, 1980; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Khan, 2001 and Mahmood, 2001).

Periodicity of cambium:

The activity of vascular cambium is not uniform, but shows great variation depending on the genetic constitution of plants and difference in the internal and external environment (Reinders-Gouwentak 1965; Philipson *et al.*, 1971). There are plants whose cambium is active throughout the entire life of the plant i.e. the cells of cambium divide continuously and the resulting cells undergo gradual differentiation to form xylem and phloem. Such type of activity usually occurs in plants growing in tropical regions (Alvim, 1964; Philipson *et al.*, 1971; Fahn, 1982). However, not all tropical trees exhibit continuous cambial activity (Coster, 1927-28; Chowdhury, 1940, 1969; Fahn and Sarnat, 1963; Mariaux, 1967; Lawton, 1972; Rao, 1972; Lu and Chiang, 1975; Yunus, 1976; Hashmi, 1977; Khan, 1977; Ghouse and Hashmi, 1979b; Iqbal, 1979; Khan, 1980; Fahn, *et al.*, 1981; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Kafeel, 1986; Zhang *et al.*, 1992, 1994, 1997; Priya and Bhat, 1999; Khan, 2001 and Mahmood, 2001).

In present study, it has been observed that the vascular cambium of all three species shows a periodic activity rather than a continuous growth as reported in other tropical species of Indian sub-continent. (Chowdhury, 1939, 1940, 1957, 1968, 1969; Chowdhury and Tandon, 1950; Paliwal and Prasad, 1970; Paliwal *et al.*, 1975; Yunus, 1976; Hashmi, 1977; Khan, 1977; Iqbal, 1979; Ghouse and Hashmi, 1979b; Khan, 1980; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Kafeel, 1986; Zhang *et al.*, 1992, 1994, 1997; Priya and Bhat, 1999; Khan, 2001; Mahmood, 2001).

Several criteria have been employed in the past to judge the initiation and the duration of cambial activity in tropical as

well as in the different temperate species. It was Priestly *et al.*, (1933) who have demonstrated for the first time, the case with which the bark separate itself from wood of a tree trunk during the active period, a phenomenon what they named as "slippage of the bark." Subsequent workers later employed several other criteria to recognize the reactivation of cambium after its winter dormancy. Some of the important findings in this connection are Knudson (1913), Lodewich (1928), Wight (1933), Chowdhury (1939), Preston and Wardrop (1949), Hodge and Wardrop (1950), Wareing (1951), Ladefoged (1952), Preston and Ripley (1954), Samish (1954), Wardrop (1954), Wareing and Roberts (1956), Wilcox (1962), Evert (1963a), Waisel and Fahn (1965a, b) Srivastava and O'Brein (1966), Robards and Kidwai (1969), Waisel *et al* (1970), Fahn (1974), Tsuda (1975), Khan (1977), Farooqui and Robards (1979), Ghouse and Hashmi (1979b), Iqbal (1979), Catesson (1980a, b), Khan (1980), Dave and Rao (1982a, b), Rao and Dave (1983a, b), Siddiqui (1983), Khan (1984), Ajmal (1985), Kafeel (1986), Khan (2001) and Mahmood (2001). In the present study, however, a number of criteria have been used in combination while studying periodicity of cambium. The initiation of cambial reactivation has been taken from the time of radial expansion of cambial initials, but the activity of cambium has been counted from the actual cell division and not from the date of histochemical changes or physical expansion of initials. The ceassation of activity has been taken by closing of cell division which normally proceeds to the histochemical change in the initials.

In all the three species investigated, the reactivation of vascular cambium has been indicated by radial expansion of cambial initials which has been described as "swelling" of

cambial cell by earlier workers (Chowdhury, 1969; Yunus, 1976, Khan, 1977; Ghouse and Hashmi, 1979b; Iqbal, 1979; Khan, 1980; Siddiqui, 1983; Khan, 1984; Ajmal, 1985; Kafeel, 1986; Ajmal and Iqbal, 1987a; Rao *et al.*, 1996; Khan, 2001 and Mahmood, 2001). This phenomenon has been observed in the present study to occur a few days before the cells start dividing to produce new derivatives in all the three species. The present finding have revealed that in *C. pentandra* swelling occurs in early May, in *F. glomerata* in mid January and in *M. oleifera* in early June.

After swelling phenomenon the cell divisions start within a week or two in the cambial zone which in turn is followed by number of histochemical changes in the initials. A decrease in density of cell protoplast, coupled with loss of chromaticity and the leaning of cell wall as a result of reduction in wall thickening and in the size of beads of radial walls. More or less similar changes in the nature and structure of cambial initials have been described by Derr and Evert (1967), Tucker and Evert (1969), Yunus (1976), Ghouse and Hashmi (1979b), Iqbal (1979), Khan (1979), Khan (1980), Siddiqui (1983), Khan (1984), Venugopal and Krishnamurthy (1987), Cui *et al.*, (1995), Khan (2001) and Mahmood (2001). The cambial activity has been noticed to initiate cell division in mid May in *C. pentandra*, in third week of January in *F. glomerata* and in mid June in *M. oleifera*.

The initiation of cell division during hot weather conditions, in *C. pentandra* and *M. oleifera* shows that this phenomenon depends upon high temperature and low humidity as has been reported earlier by Chowdhury (1969) in temperate and tropical trees, Ghouse and Hashmi (1979a,

1980b) in *Polyalthia longifolia, Delonix regia* and *Mimusops elengi*, Iqbal (1979) in *Acacia nilotica*, Khan (1980) in *Eugenia jambolana and Callistemon citrinus,* Rao and Dave (1981) in *Tectona grandis,* Ghouse and Hashmi (1983) in *Mimusops elengi*, Siddiqui (1983) in *Ficus infectoria*, Khan (1984) in *Bombax malabaricum,* Ajmal (1985) in *Sterbulus asper,* Kafeel (1986) in *Bauhinia variegata* Paliwal and Paliwal (1992) in *Rhododendron arboreum.* Khan, (2001) in *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna,* Mahmood (2001) in *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii,* Horacek *et al.,* (2003) in *Quercus* robur. However in *F. glomerata* cambial activity is noticed from early January to September and is not found to be influenced by high temperature and low humidity.

The cessation of cambial activity occurs in late November in *C. pentandra* and *M. oleifera* while in *F. glomerata* dormancy is attained in late September. Thus it appears that in two investigated species, fall in temperature brings down the dormancy as reported earlier by Rao and Dave (1981) in *Tectona grandis,* Siddiqui (1983) in *Ficus infectoria* and *Ficus religiosa*, Ghouse and Hashmi (1983) in *Mimusops elengi*, Khan (1984) in *Bombax malabaricum*, Paliwal and Paliwal (1992) in *Rhododendron arboreum,* Khan, (2001) in *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna,* Mahmood (2001) in *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii.* Contrary to this, Khan (1980) has reported that in *Eucalyptus maculata*, the fall in temperature do not impede the activity of cambium but appeared to improve it which continued up to March. More or less similar situation has been noticed in case of *F. glomerata* and it is

found to continue up to September when temperature is sufficient at Aligarh.

In the presently investigated species, the cambium remains active for about 7 months in *C. pentandra* 9 months in *F. glomerata* and 6 months in *M. oleifera*. More or less similar prolonged tends of duration of 5-9 months of radial growth has been reported earlier by Amos *et al.*, (1950), Chowdhury (1968), Fahn (1974), Yunus (1976), Hashmi (1977), Khan (1977), Iqbal (1979), Khan (1980), Siddiqui (1983), Khan (1984), Zhang *et al.* (1997), Khan (2001) and Mahmood (2001). However, Paliwal and Prashad (1970) and Paliwal *et al.* (1975) have reported short duration, as short 3 to 4 months, to be the active period of radial growth. In Israel, Fahn (1962) and Fahn *et al.* (1981) classified trees and shrubs on the basis of their cambial activity and found the cambial activity last for duration of about 4 months in *Zygophllun dumosum, Quercus ithaburensis* and *Crataegus azarolus*.

Xylem and phloem production:

In all the three species investigated, the xylem and phloem production shows considerable variation with time and duration. In *C. pentandra* and *F. glomerata* the newly produced derivatives first differentiate into phloic elements in the months of May and January respectively. The xylem production occurs in June in *C. pentandra* and in February in *F. glomerata*. The phloem production precedes that of xylem in both the above mentioned species. A similar situation of phloem and xylem production has been reported earlier in a number of tropical as well as temperate forms both with deciduous and evergreen habits. Such as *Vitis vinifera* (Esau 1948), *Pyrus communis* (Evert 1961), *P. malus* (Evert, 1963a), *Pinus banksiana*, *P. resinosa* and *P. strobus* (Alfieri and Evert 1968), *Populus tremuloides* (Davids and Evert 1968), *Acer negundo* (Tucker and Evert 1969), *Isoetes taisanensis* (Chiang, 1976), *Dalbergia sissoo* (Yunus 1976), *Acacia, nilotica* and *Prosopis spicigera* (Iqbal, 1979), *Polyalthia, longifolia* (Ghouse and Hashmi, 1979b), *Haloptelea integrifolia* (Rao and Dave 1984), *Prosopis spicigera* (Iqbal and Ghouse 1985b), *Ficus rumphii* (Ajmal and Iqbal 1987a), *Rhododendron arboreum* (Paliwal and Paliwal 1992), *Juniperus californica* (Alfieri *et al.*, 1993). However, there are studies which have reported that xylem formation precedes that of phloem. Khan (1977) in *Psidium guajava*, an evergreen member of Myrtaceae has found xylem production to precede that of phloem. Similarly, in *Mimusops elengi*, an evergreen member of Sapotaceae (Hashmi, 1977) in *Delonix regia,* a deciduous member of leguminosae (Ghouse and Hashmi, 1980b), in *Callistemon citrinus, Eucalyptus maculata, Eugenia jambolana*, all evergreen trees (Khan 1980), in *Ficus infectoria* (Siddiqui, 1983), in *Sterbulus asper*

(Ajmal and Iqbal 1987b) and in *Bombax ceiba* Brume (Rao *et al.,* 1996) it was found that xylem formation precedes that of phloem. In a number of temperate forms also, the xylem production is found to precede phloem formation (Elliott, 1935; Artschwager, 1945; Fraser, 1952; Bannan, 1955 Khan, 2001; Mahmood, 2001.

In *M. oleifera* simultaneous production of phloem and xylem has been observed in the month of June. A similar simultaneous production of xylem and phloem has also been reported in number of cases, such as in *Tilia americana* by (Evert 1962) and Deshpande (1967), in *Vitis riparia* by Davis and Evert (1970), in *Ficus religiosa* by Siddiqui (1983), in *Bombax malabaricum* by Khan (1984), in *Bauhinia purpurea* and *B. variegata* by Kafeel (1985) and in *Pinus roxburghii* by Khattak and Majeed (1993) by Khan (2001), in *Pterospermum acerifolium,* by Mahmood (2001), in *Emblica officinalis*.

In *C. pentandra*, well before the commencement of cambial activity, a few layers of new phloem are produced in January. It seems to have developed from the outer derivatives of the cambium, which is produced at the inactivation of last growth season and remained in less differentiated or undifferentiated form. As it is not the product of current year's cambial growth, it is termed as precursor phloem. Such type of precursor phloem formation has also been reported in some Indian tropical trees by Ghouse and Hashmi (1979a, 1980b), Khan (1980), Siddiqui (1983), Khan (1984), Kafeel (1986) as well as in some temperate trees like white pine by Abbe and Crafts (1939), pecan by Artschwager (1950), *Pyrus communis* and *P. malus* by Evert (1961, 1963a), *Robinia pseudoacacia* by Derr and Evert (1967) and in *Populus*

tremuloides by Davis and Evert (1968) in *Emblica officinalis* by Mahmood (2001).

The present study has revealed that the quantum of xylem produced is substantially higher than phloem in all the three species investigated. This is in concurrence with the earlier studies by Waisel *et al.*, (1966), in *Eucalyptus camaldulensis,* Yunus (1976) in *Dalbergia sissoo,* Hashmi (1977) in *Delonix regia, Mimusops elengi* and *Polyalthia longifolia,* Iqbal (1979) in *Acacia nilotica* and *Prosopis spicigera,* Khan (1980) in *Callistemon citrinus, Eucalyptus maculata* and *Eugenia jambolana*, Siddiqui (1983) in *Ficus infectoria* and *F. religiosa,* Khan (1984) in *Bombax malabaricum*, Khan (2001) in *Jacaranda mimosaefolia, Pterospermum acerifolium, Terminalia arjuna,* Mahmood (2001) in *Alstonia scholaris, Emblica officinalis, Putranjiva roxburghii*. However, in none of the species investigated at present or studied earlier, the ratio of xylem and phloem comes as high as 14:1 or 15:1 as has earlier been reported by Wilson (1963) in *Abies concolor* and by Bannan (1955) in *Thuja occidentalis* respectively. According to Wilson (1964), the ratio of the xylem layers produced to the number of phloem layers may be 10:1 in vigorous conifers while only 1:1 in slow growing ones. In the present study, the ratio of xylem produced to that of phloem was found to be 2.5:1 in *C. pentandra*, 8:1 in *F. glomerata* and 4:1 in *M. oleifera*. More or less similar ratio of phloem and xylem 2:1 in *Jacaranda mimosaefolia* 4.5:1 in *Pterospermum acerifolium* and 9:1 in *Terminalia arjuna* has been reported by Khan (2001). But contrary to this, Khan (1977) in *Psidium guajava* found that phloem produced was twice the amount of xylem in a calendar year.

Longevity of phloem:

In most of the dicotyledons, the functioning part of the phloem is restricted to that of secondary phloem, which is produced in the last growth season. Sometimes, before the cambium begins to produce new phloem, all or most of the sieve elements produced in the previous season cease to function (Fahn 1982). However in some plants, e.g., *Tilia*, the sieve tubes remain active for a number of years and no changes have been observed to take place during the winter (Evert 1962). In *Vitis*, the phloem was observed to be active for two seasons, but unlike *Tilia*, *Vitis* lays down thick layers of callose with the onset of winter. These layers are subsequently reabsorbed in the spring before the renewal of cambial activity (Esau 1948, Bernstein and Fahn 1960). In *Fraxinus americana*, the non functional sieve tubes of the previous year are reactivated in spring and remain functional during the period, when the buds develop and the young leaves grow (Zamaski and Zimmermann 1979). It should be mentioned that in plants with included phloem, e.g., *Bougainvillea*, and the woody species of Chenopodiaceae, the phloem strands remain active for many years (Fahn and Shchori, 1967). In *Hevea brasiliensis*, planted on Hainan Island (China), the sieve elements function for one and a half year to two years (Wu and Hao 1986). However, in majority of plants, the phloem turns nonfunctional in the same season in which it is produced (Huber, 1939; Esau, 1945, 1950, 1965; Artschwager, 1950; Evert, 1961, 1963a; Davis and Evert, 1966, 1968, 1970; Derr and Evert, 1967; Alfieri and Evert, 1968; Tucker, 1968; Tucker and Evert, 1969; Lawton, 1972; Khan, 1977; Ghouse and Hashmi, 1979a, 1980b, Khan, 1980; Fahn, 1982; Siddiqui, 1983; Khan, 1984; Khan 2001, Mahmood, 2001). In the

present investigation also, the sieve-tube members were found to become non-functional in the same season in which they are produced due to accumulation of thick layers of callose which covers the sieve plates and lateral sieve areas. Similar inactivation of sieve elements by callose plugging has also been reported by Alfieri *et al.*, (1983), Deshpande and Rajendrababu, (1985), Rao *et al.*, (1996), Khan (2001), Mahmood (2001). In *C. pentandra* phloem formation occurs from May to July, in *F. glomerata* in January, February and July and in *M. oleifera* in June, August, September and November. However, in *C. pentandra* 'Precursor phloem' formation occurs in the month of January out of over wintered mother cells. This precursor phloem about 150 μm remains functional for about 4 months and turns nonfunctional later when the current year's phloem is produced in the month of May. Precursor phloem formation has also been reported by Khan (1980) in *Callistemon citrinus* and *Eugenia jambolana*, Siddiqui (1983) in *Ficus religiosa*, Khan (1984) in *Bombax malabaricum*, and Kafeel (1986) in *Bauhinia variegata*, Mahmood (2001) in *Emblica officinalis*. The current year's phloem functions for about 7 months. In *F. glomerata* and *M. oleifera* the phloem is produced twice in a calendar year i.e. first in January, February and then in July in *F. glomerata* while in *M. oleifera* first in June, July, August, September and than in November. Similar production of phloem, twice in a year, has been reported by Khan (1977) in *Psidium guajava*, Mahmood (2001) in *Putranjiva roxburghii*. Thus, in both *F. glomerata* and *M. oleifera* the longevity of phloem is about 11 months as has been reported in *Jacaranda mimosaefolia*, *Pterospermum acerifolium* and *Terminalia arjuna* by Khan (2001).

Abstract

ABSTRACT

The present study on the structure and behaviour of vascular cambium and its derivatives tissues – the food conducting (secondary phloem) and the water conducting (secondary xylem) pathways has been under taken in relation to different weather conditions of the study site and age of the selected trees *Ceiba pentandra* (L.) Gaertn., *Ficus glomerata* Roxb. *and Moringa oleifera* Lamk. for two consecutive years (2003 & 2004). The findings are summarized as follows:

The vascular cambium is semi-stratified in *C. pentandra*, typical non-stratified in *F. glomerata* and *M. oleifera*. It forms a continuous cylinder and is made up of fusiform and ray initials. The fusiform initials are found to vary in length from 212.50 –712.50 μm in *C. pentandra*, 150.-612.50 μm in *F. glomerata* and 125.00 – 437.50 μm in *M. oleifera*. The fusiform initials undergo considerable size variation with growing girth of the stem axis. The length of fusiform initials shows an increasing trend from top toward the base of the tree in *C. pentandra* and in *F. glomerata* initially it increases and exhibit declining trend at the base while in *M. oleifera* the length exhibit increasing tendency with the advancing age and soon gets stabilized near the base. This increase in length goes up to 24% in *C. pentandra* 23% in *F. glomerata* and 46% in *M. oleifera* respectively.

The ray initials multiply to become more in number as the trunk grows older and wider. New rays arise either by cutting off tips or sides of fusiform initials or by transverse segmentation of the later.

The wood is diffuse porous in all the three species investigated. The pores are either solitary or in radial multiples of 2-12.

The average length of vessel elements shows an increase with the increasing girth of the axis in *C. pentandra*. In *F. glomerata* and *M. oleifera*, average length of vessel elements initially increases with the age and after experiencing a slight decline again there is a gain in length with the advancing age. The radial and tangential diameter of vessel elements in *C. pentandra* and *F. glomerata* first undergo expansion with increasing age of the axis which is followed by a declining tendency near the basal regions. In *M. oleifera* radial diameter shows an initial increase and appear to be followed by constancy while tangential diameter shows an increasing tendency from top towards the base. The length of vessel elements vary from 100.00-500.00 μm in *C. pentandra*, 62.50-525.00 μm in *F. glomerata* and 125.00-400.00 μm in *M. oleifera* in different months of a calendar year with average length of vessel elements is measured 353.46 in *C. pentandra*, 264.00 μm in *F. glomerata* and 279.04 μm in *M. oleifera* under different seasonal influences.

The mean length of xylem fibres shows a positive increase with growing size of the trunk and the average length of fibres has been found to vary from 1134.00-1828.00 μm in *C. pentandra*, 1031.50-1416.00 μm in *F. glomerata* and 571.00-736.00 μm in *M. oleifera.*

The bark as usual is made up of three distinct zones viz, conducting phloem, non-conducting phloem and periderm. The sieve-tube members possess mostly oblique sieve plates on their end wall in *C. pentandra*, slightly oblique to transverse in

F. glomerata and mostly transverse in *M. oleifera*. They vary in length from 162.50-450.00 μm in *C. pentandra*, 150.00-412.50 μm in *F. glomerata* and from 187.50-400.00 μm in *M. oleifera* and their average length is measured 324.42 μm, 266.08 μm and 269.29 μm respectively due to seasonal influence. They occupy about 28% transactional area in *C. pentandra*, 25% in *F. glomerata* and 27% in *M. oleifera*.

A gradual increase in the length of sieve-tube members along the tree axis of varying girth has been observed in *C. pentandra* and *M. oleifera*, while it declines near the base in case of *F. glomerata*.

The phloem fibres are distributed in the secondary phloem in a characteristics pattern in *C. pentandra*, *F. glomerata* and *M. oleifera*. They grow in length 2.427-4.298 times over the length of their mother initials in the different species investigated. They vary in length from 650.00-2500.00 μm in *C. pentandra*, from 625.00-2300.00 μm in *F. glomerata* and from 250.00-1300.00 μm in *M. oleifera* in different months of a calendar year.

The activity of vascular cambium initiates at different times in different species. Swelling of cambial cells occur in early May in *C. pentandra*, in mid-January in *F. glomerata* and in early June in *M. oleifera*. The cells begin to divide in mid May in *C. pentandra*, in late January in *F. glomerata* and in mid June in *M. oleifera*.

The cambium turns dormant in late November in *C. pentandra* and *M. oleifera* while in *F. glomerata* dormancy is attained in late September. The total amount of xylem produced in measures about 1950 μm in *C. pentandra*, 2150 μm in *F. glomerata* and 1600 μm in *M. oleifera*. In *C.*

pentandra and *F. glomerata* the newly produced derivatives differentiate first into phloic elements, but in *M. oleifera*, the newly produced derivatives differentiate into phloic as well as xylem elements simultaneously.

The phloem production takes place in the months of May, June and July in *C. pentandra*, in January, February and July in *F. glomerata* and in June, July, August, September and November in *M. oleifera*. Precursor phloem is noticeable in *C. pentandra* in the month of January. The total amount of phloem produced during a calendar year is about 645 μm and 150 μm precursor phloem in *C. pentandra*. In *F. glomerata* and *M. oleifera*, the phloem production is about 260 μm and 430 μm respectively. The cambium remains active for about 7 months in *C. pentandra*, 9 months in *F. glomerata* and 6 months in *M. oleifera*.

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* original note seen.

Photo-Plates

PLATE-I

Photomicrographs of cambial strips of *C. pentandra*

A: T.L.S. cambium showing terminal merger of rays (unlabelled arrow) at 20X.

B, E: T.L.S. active cambium at 40X.

C: T.L.S. cambium showing pseudo-transverse division (unlabelled arrow) at 40X.

D: T.L.S. cambium showing lateral merger of rays (unlabelled arrow) 10X.

F: T.L.S. dormant cambium showing laterally cut new ray initial (unlabelled arrow) at 40X.

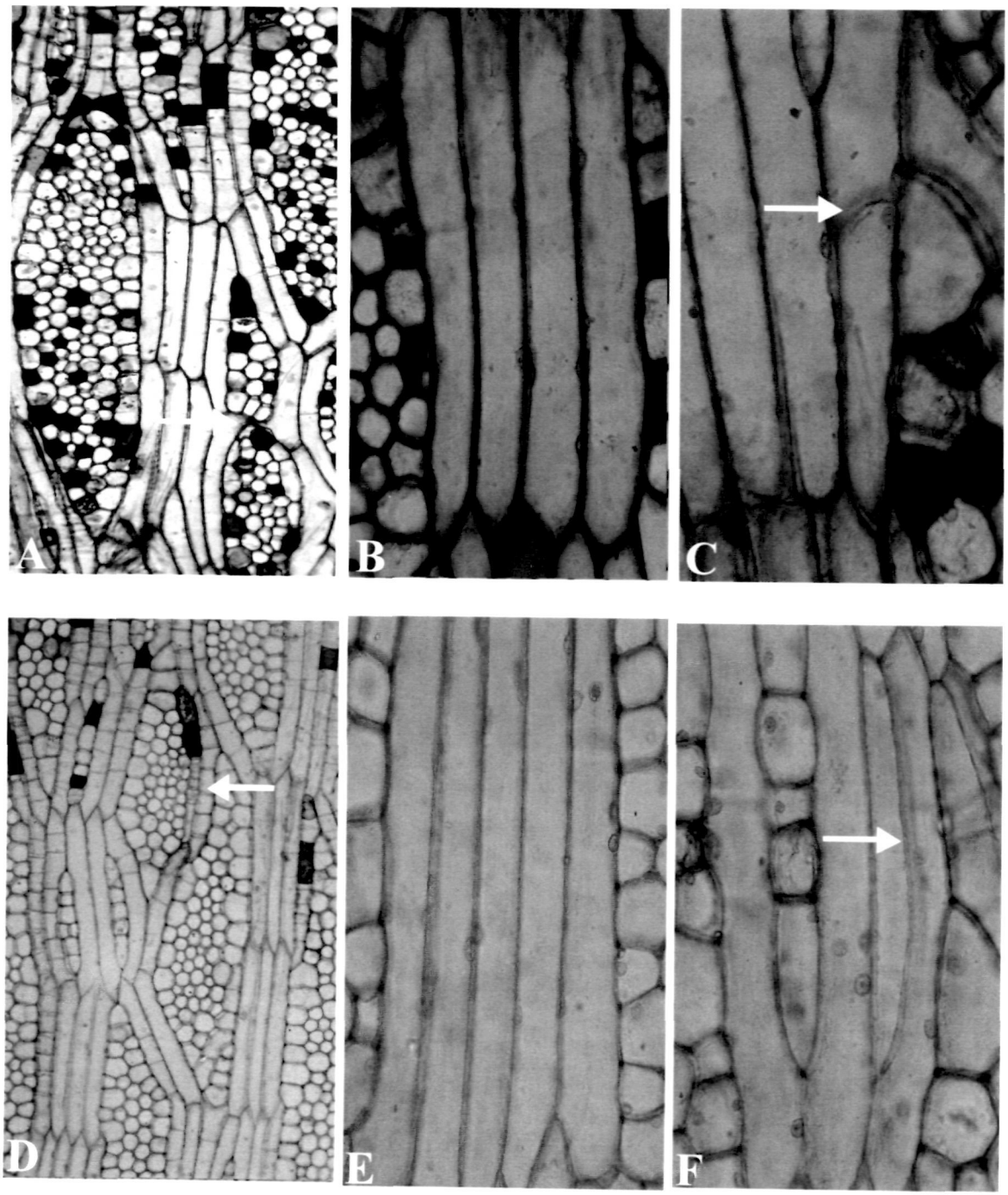

PLATE-I

PLATE-II

Photomicrographs of cambial strips of *C. pentandra*

A: T.L.S. cambium showing terminal merger of rays (unlabelled arrow) at 10X.

B: T.L.S. cambium showing splitting of rays (unlabelled arrows) at 10X.

C: T.L.S. cambium showing terminal fusion and splitting of rays (unlabelled arrows) at 10X.

D: T.L.S. cambium showing formation of rays (unlabelled arrows) at10X.

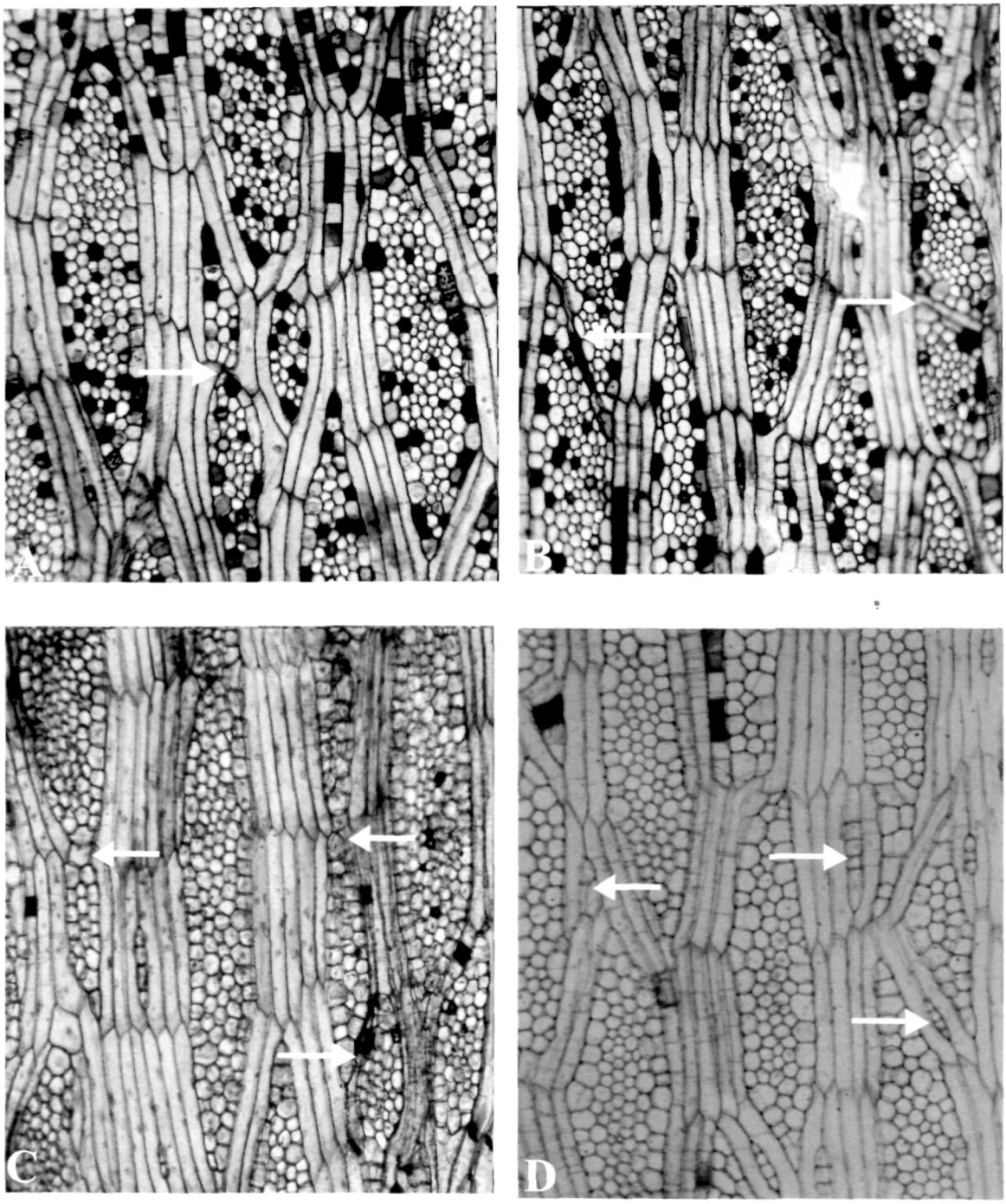

PLATE-II

PLATE-III

Photomicrographs of cambial strips of *F. glomerata*

A: T.L.S. active cambium at 10X.

B: T.L.S. cambium showing splitting of rays (unlabelled arrows) at 10X.

C: T.L.S. cambium showing transverse septation and terminal segmentation of fusiform initial and newly produced ray (unlabelled arrows) at 40X.

D: T.L.S. cambium showing transverse segmentation of fusiform initials and newly produced ray (unlabelled arrows) at 10X.

E: T.L.S. cambium showing pseudo-transverse division (unlabelled arrows) at 40X.

F: T.L.S. dormant cambium showing pseudo-transverse division (unlabelled arrow) at 40X.

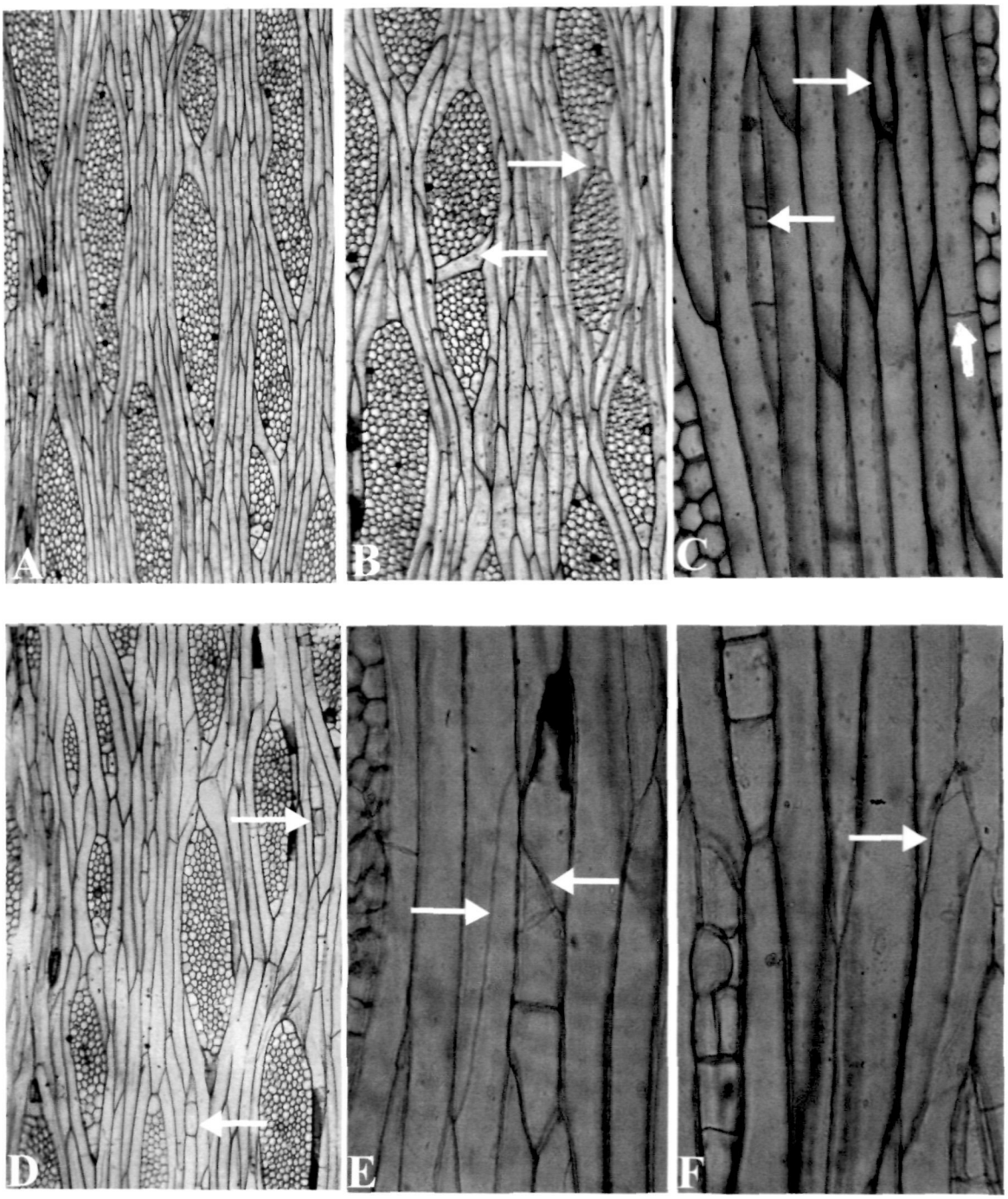

PLATE-III

PLATE-IV

Photomicrographs of cambial strips of *F. glomerata*

A: T.L.S. dormant cambium showing pseudo-transverse division and terminal segmentation of fusiform initials (unlabelled arrows) at 40X.

B: T.L.S. cambium showing transverse wall formation in newly produced ray (unlabelled arrow) at 40X.

C, D: T.L.S. cambium showing pseudo-transverse division and formation of laterally cut ray initial cell (unlabelled arrows) at 40X.

E: T.L.S. cambium showing pseudo-transverse division and lateral fusion of rays (unlabelled arrows) at 40X.

F: T.L.S. cambium showing pseudo-transverse division and laterally cut lens shaped ray initial cell (unlabelled arrows) at 40X.

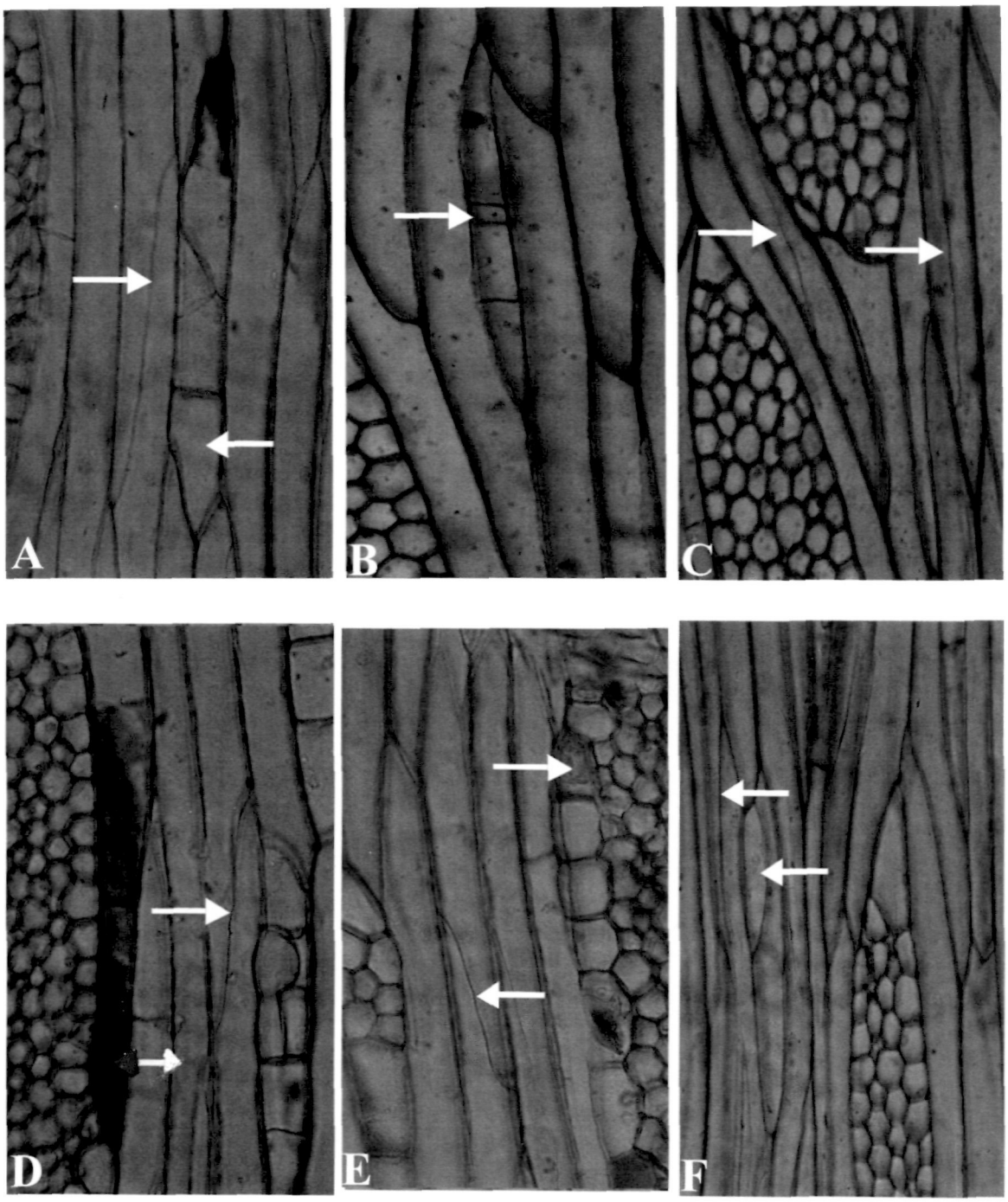

PLATE-IV

PLATE-V

Photomicrographs of cambial strips of *M. oleifera*

A: T.L.S. active cambium showing pseudo-transverse division (unlabelled arrow) at 10X.

B: T.L.S. cambium showing pseudo-transverse division (unlabelled arrows) at 10X.

C: T.L.S. cambium showing pseudo-transverse division (unlabelled arrows) at 40X.

D: T.L.S. dormant cambium at 10X.

E & F: same as D at 40X.

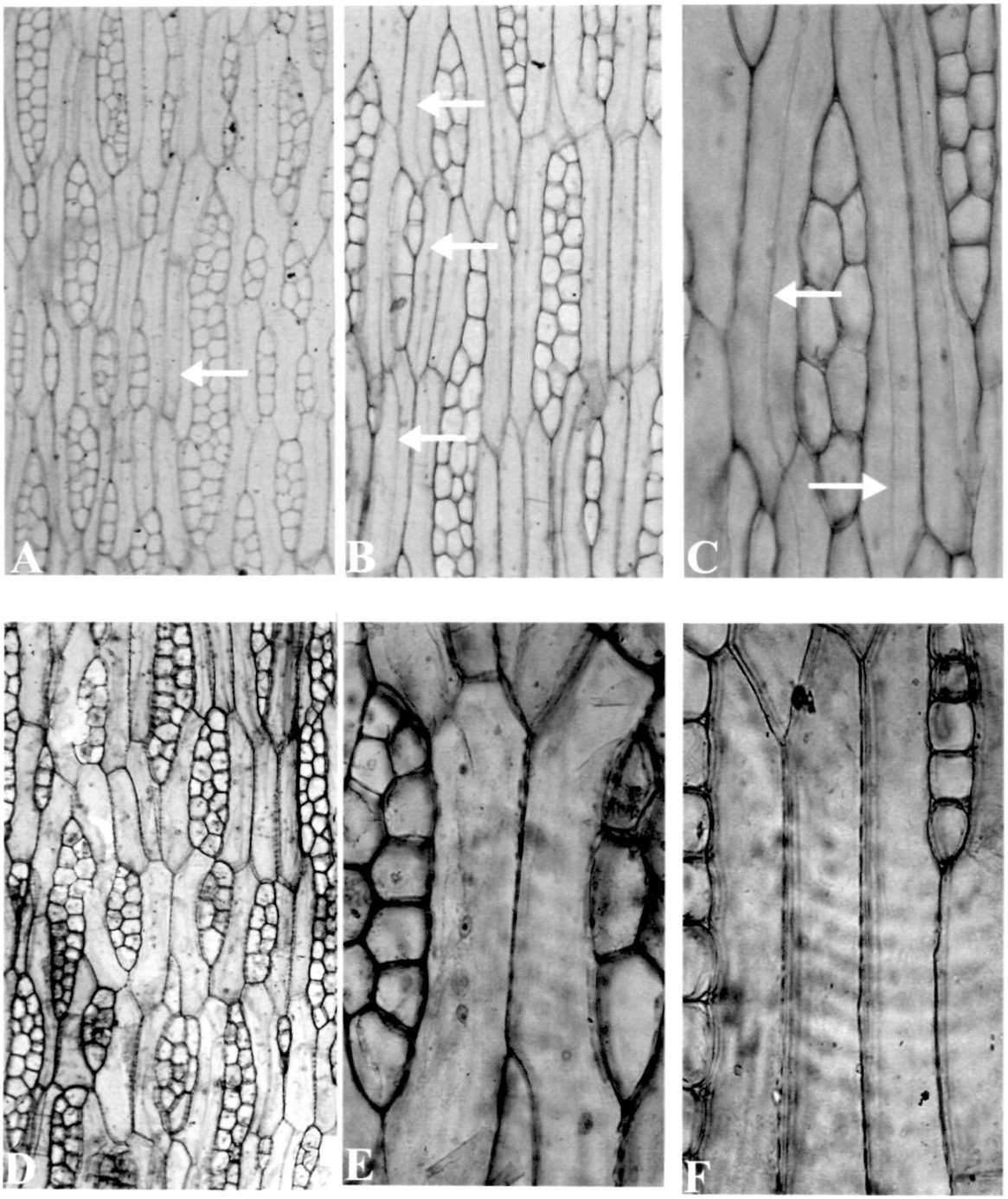

PLATE-V

PLATE-VI

Photomicrographs of cambial strips of *M. oleifera*

A: T.L.S. cambium showing lateral & terminal merger of rays (unlabelled arrows) at 10X.

B: T.L.S. cambium showing pseudo-transverse division and formation of ray initials (unlabelled arrows) at 40X.

C: T.L.S. cambium showing lateral fusion of ray initials (unlabelled arrow) at 40X.

D: T.L.S. cambium showing laterally cut lens shaped ray initial cell (unlabelled arrow) at 40X.

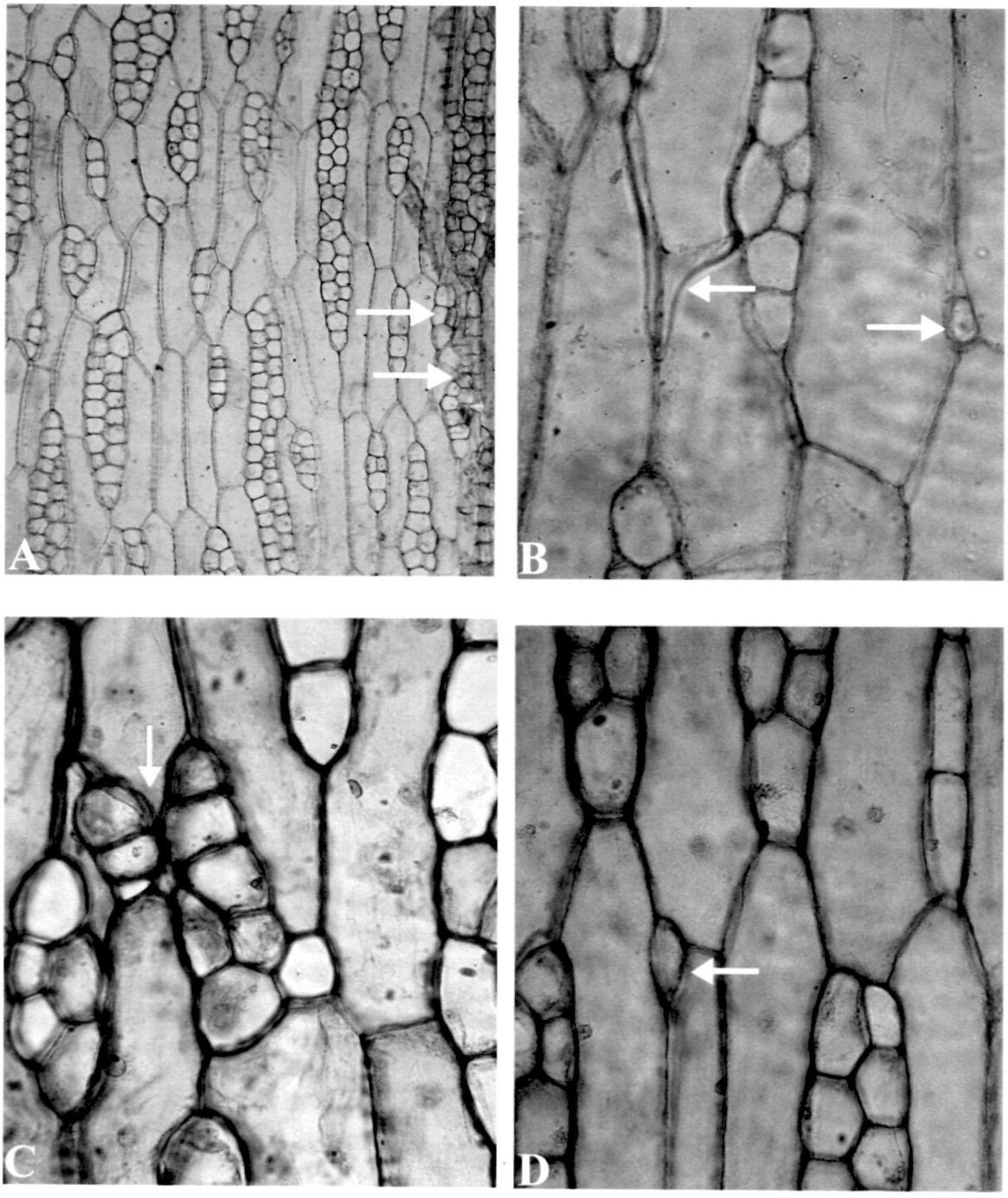

PLATE-VI

PLATE-VII

Photomicrographs of wood samples of *C. pentandra*

A: T.L.S. showing arrangement of vessel element and overcrowded reduced bordered pits on their lateral wall (unlabelled arrows) at 10X.

B: T.L.S. showing scalariform pits on their lateral walls of vessel elements (unlabelled arrow) at 10X.

C: T.L.S. showing vessels, xylem rays, sclerenchyma and parenchyma at 10X.

D: T.L.S. showing overcrowded reduced bordered pits on lateral walls of vessel elements at 40X.

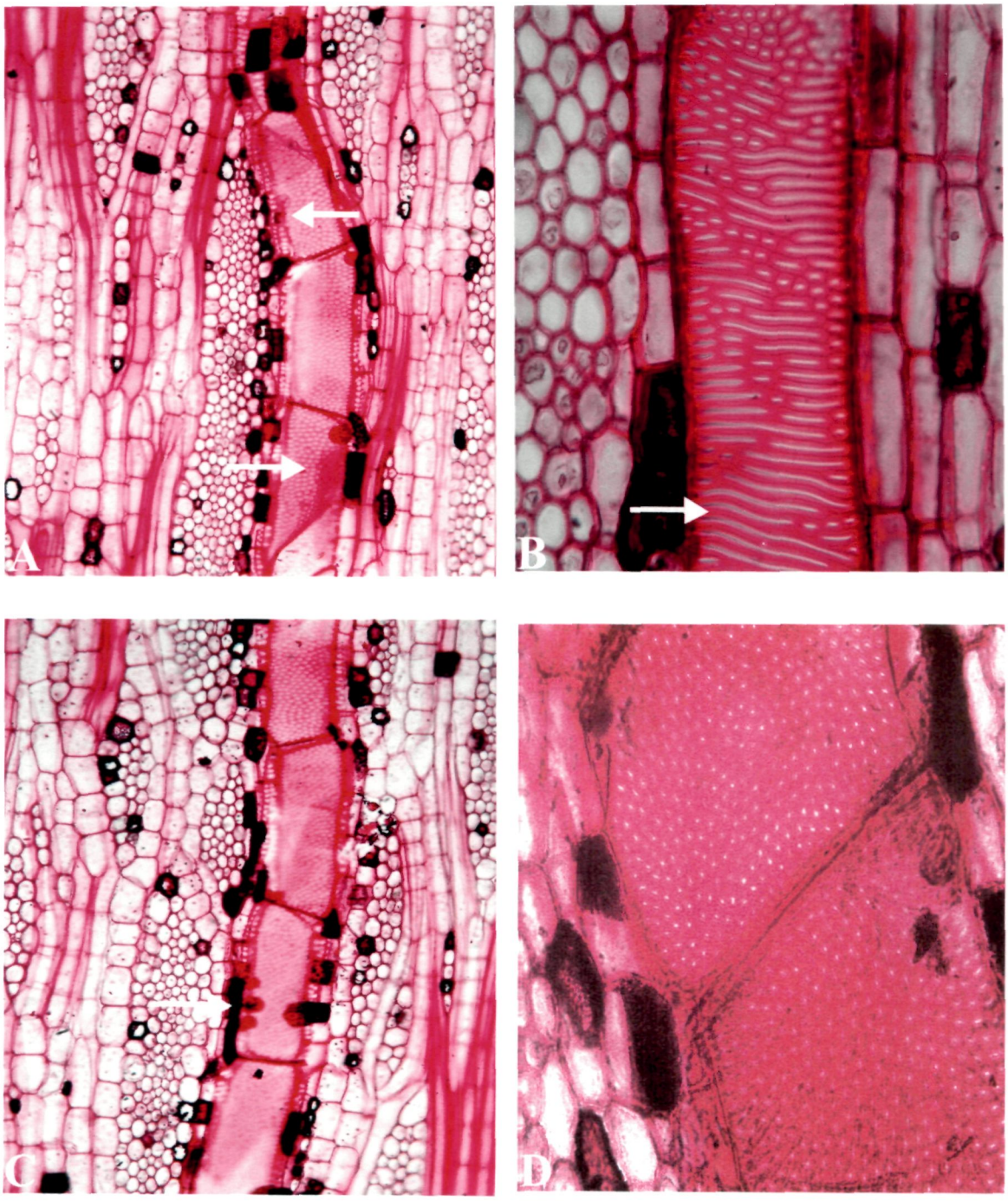

PLATE-VII

PLATE-VIII

Photomicrographs of wood samples of *C. pentandra*

A: T.S. showing vessels and other components (unlabelled arrows) at 40X.

B: T.S. showing tylosed vessels (unlabelled arrows) at 40X.

C: T.L.S. showing pores at 40X.

D: R.L.S. showing homogenous rays at 10X.

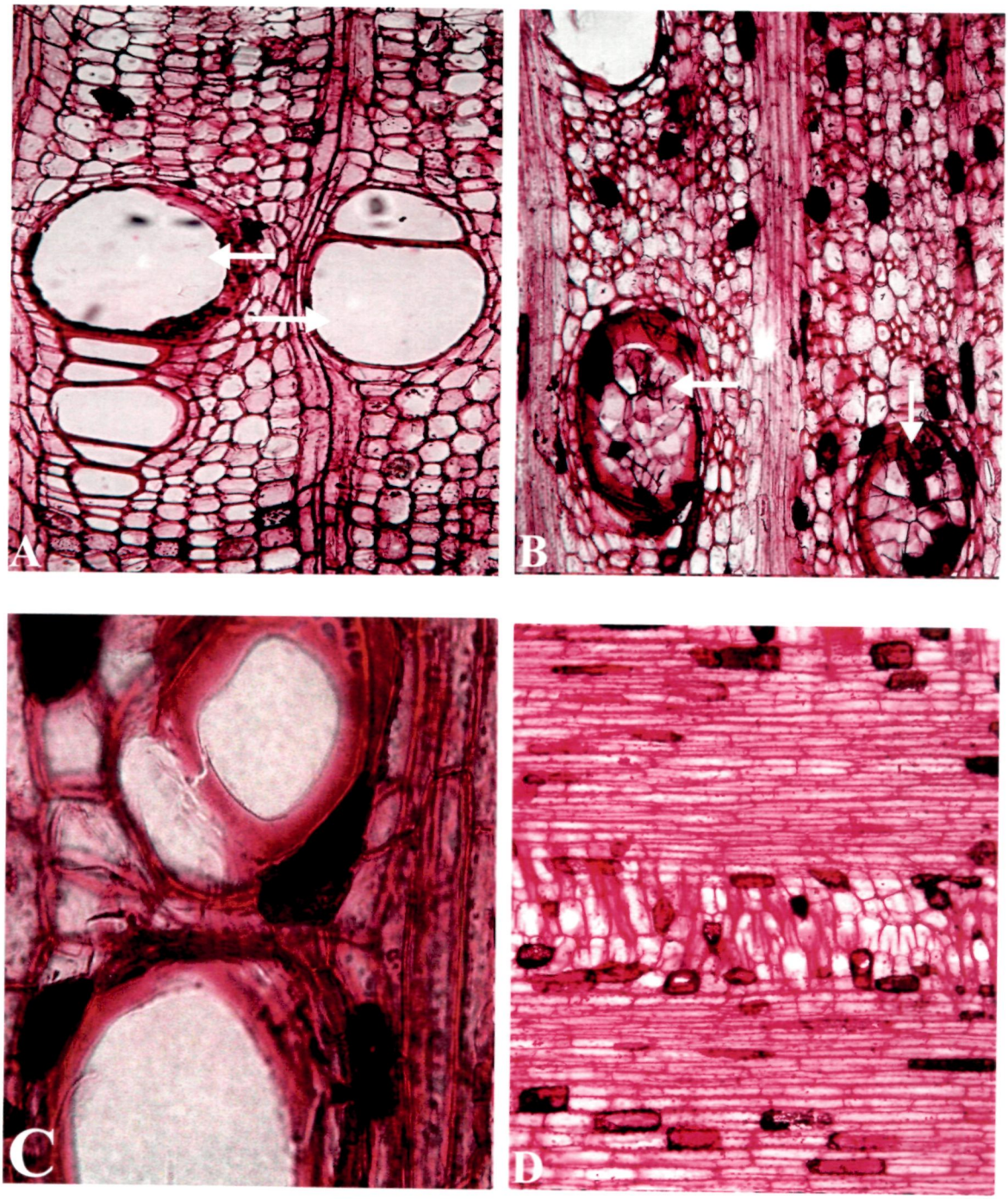

PLATE-VIII

PLATE-IX

Photomicrographs of wood samples of *F. glomerata*

A: T.L.S. showing arrangement of vessels (unlabelled arrow) at 10X.

B, D: T.L.S. showing vessels having overcrowded reduced bordered pits (unlabelled arrows) at 40X.

C: T.L.S. showing different xylem components at 10X.

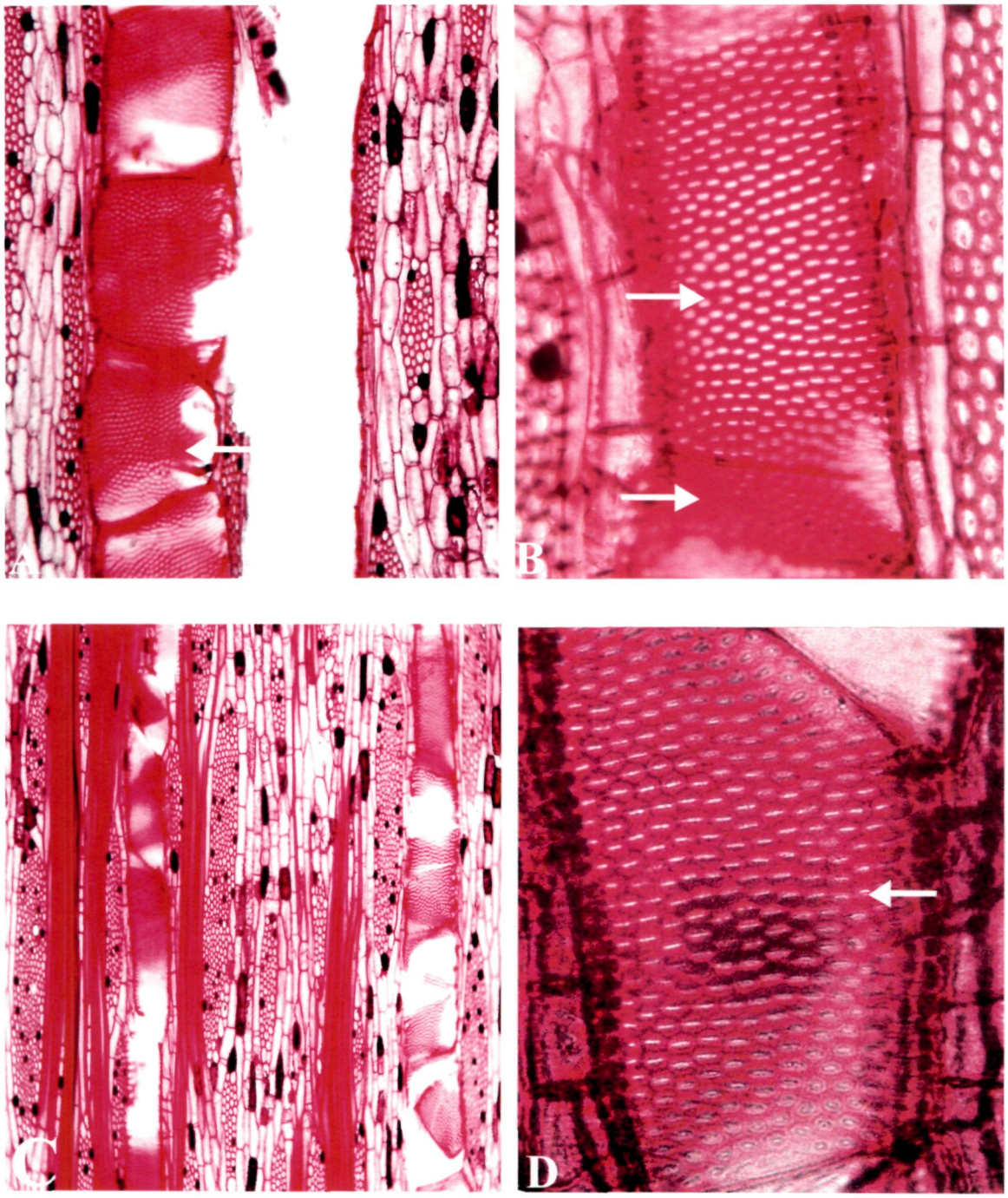

PLATE-IX

PLATE-X

Photomicrographs of wood samples of *F. glomerata*

A: T.L.S. showing rays and sclerenchyma (unlabelled arrows) at 10X.

B: T.S. showing tylosed vessels, multiple pores, rays and sclerenchyma (unlabelled arrows) at 10X.

C: T.L.S. showing sclerenchyma fibres (unlabelled arrows) at 10X.

D: R.L.S. showing homogenous rays at 10X.

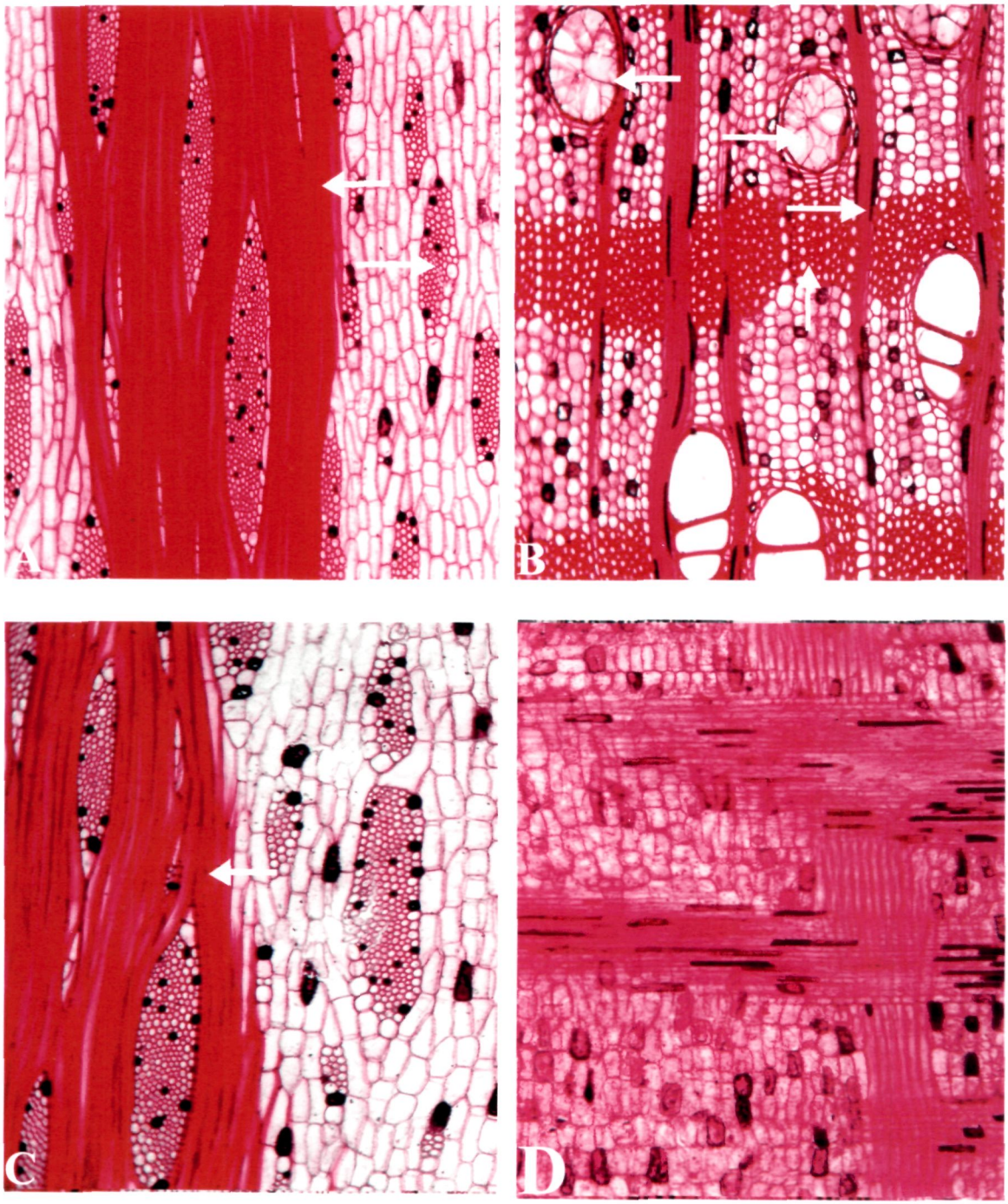

PLATE-X

PLATE-XI

Photomicrographs of wood samples of *M. oleifera*

A: T.L.S. showing arrangement of vessels and rays (unlabelled arrows) at 10X.

B: T.L.S. showing scalariform pits on lateral walls of vessels (unlabelled arrow) at 40X.

C: T.L.S. showing vessels having overcrowded reduced bordered pits (unlabelled arrow) at 40X.

D: T.S. showing solitary pores (unlabelled arrows) at 10X.

E: T.S. showing multiple pores at10X.

F: R.L.S. showing homogenous rays at 10X.

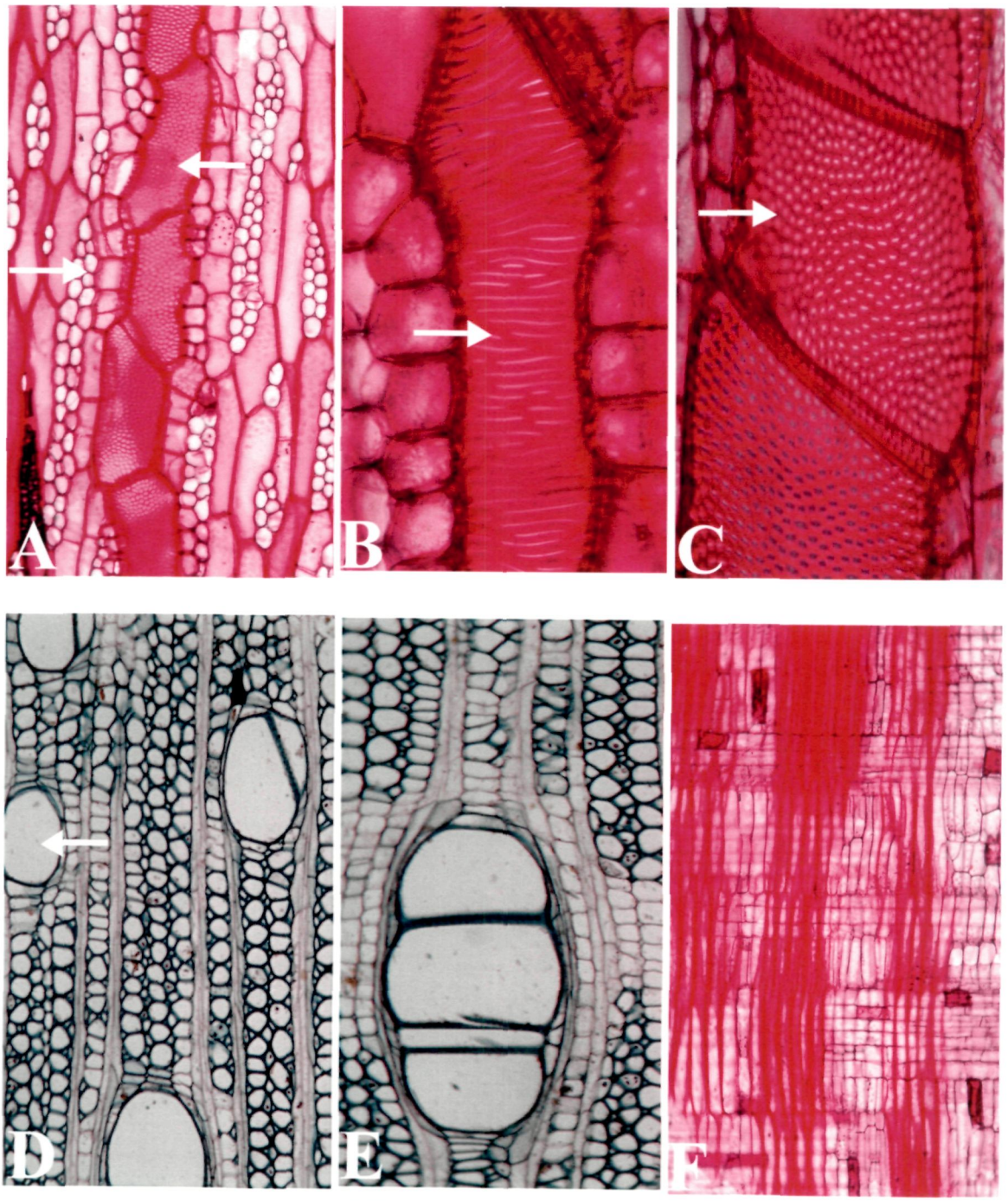

PLATE-XI

PLATE-XII

Photomicrographs of bark samples of *C. pentandra*

A: T.L.S. showing sieve tubes and sieve plates (unlabelled arrows) at 10X.

B: T.L.S. showing callose plugs on the end walls of sieve tube members and lateral sieve areas (unlabelled arrows) at 40X.

C: T.S. showing sclerenchyma and sieve plate (unlabelled arrows) at 10X.

D: T.S. showing crushed sieve elements, sieve plate, and sieve tube with companion cell (unlabelled arrows) at 40 X.

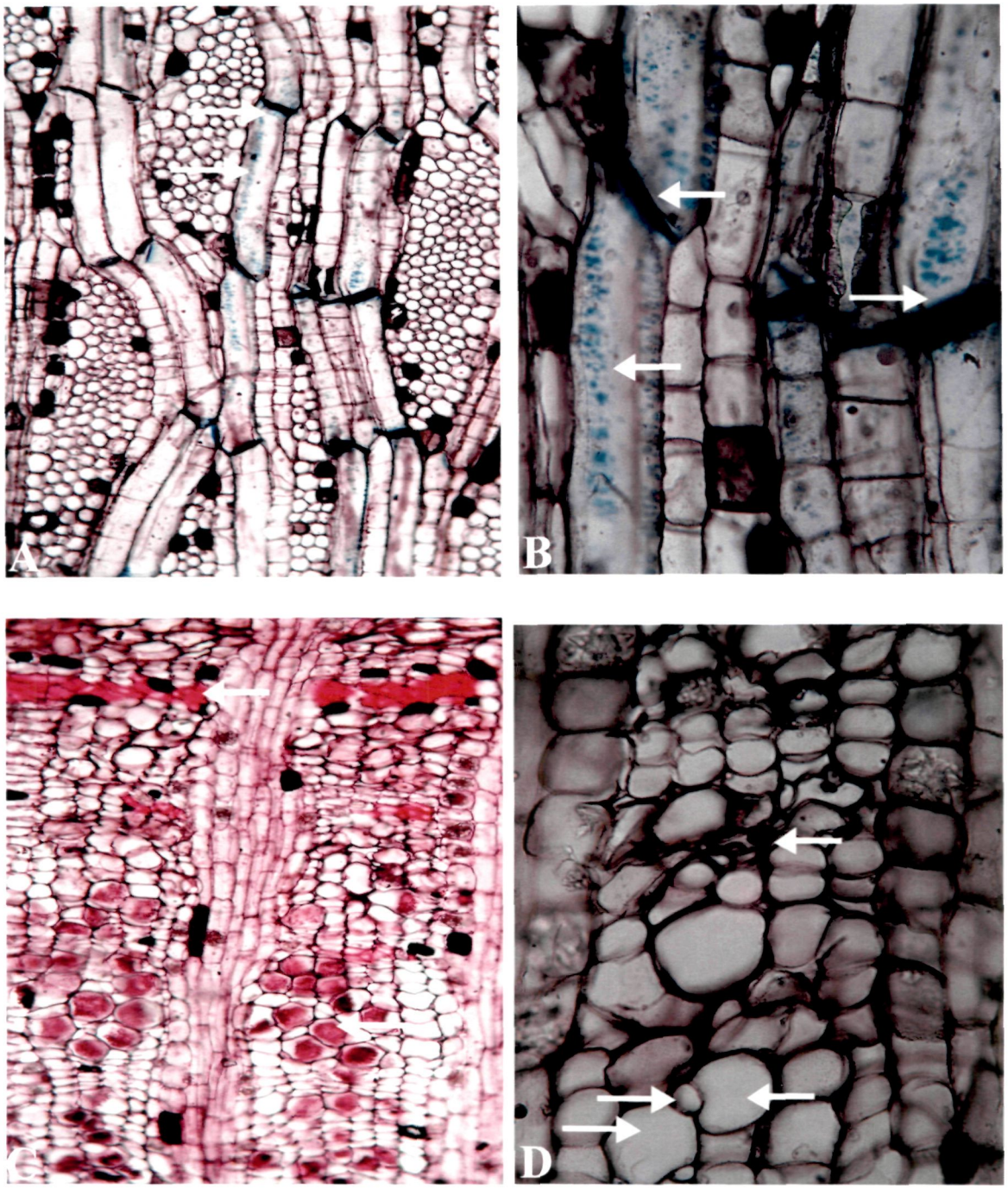

PLATE-XII

PLATE-XIII

Photomicrographs of bark samples of *F. glomerata*

A: T.L.S. showing sieve tubes and sieve plates (unlabelled arrows) at 10X.

B: T.L.S. showing callose plugs on sieve plate and lateral sieve areas (unlabelled arrows) at 40X.

C: T.S. showing sieve tube with companion cell and sieve plate (unlabelled arrows) at 40X.

D: T.S. showing crushed sieve elements, sieve plate and companion cell (unlabelled arrows) at 40X.

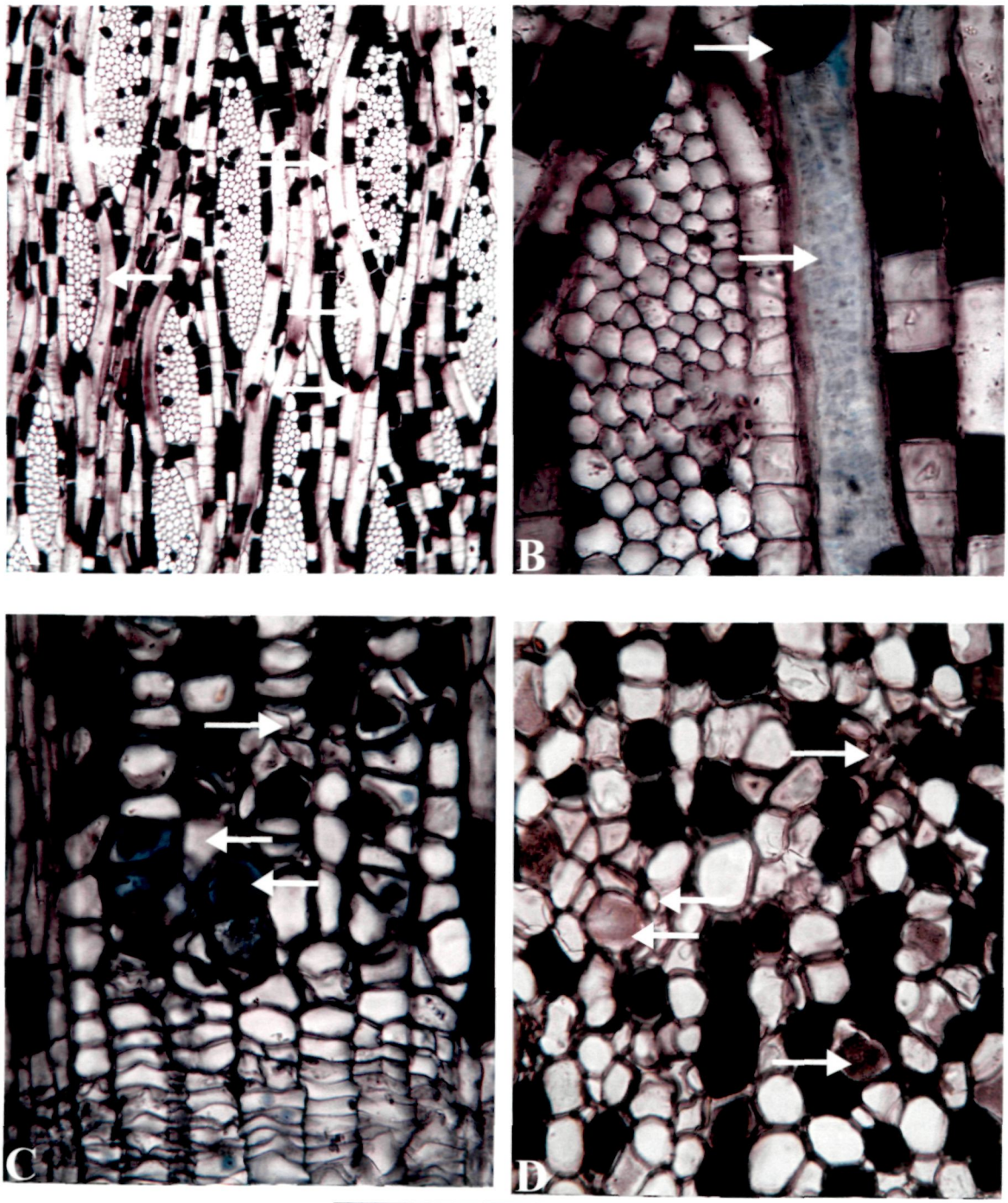

PLATE-XIII

PLATE-XIV

Photomicrographs of bark samples of *M. oleifera*

A: T.L.S. showing arrangement of sieve tube members, sieve tubes with sieve plates (unlabelled arrows) at 10X.

B: T.L.S. showing sieve plate and lateral sieve areas (unlabelled arrows) at 40X.

C: T.S. showing sieve tube with companion cell and sieve plate (unlabelled arrows) at 10X.

D: T.S. showing sieve tubes without companion cell and ray (unlabelled arrows) at 40X.

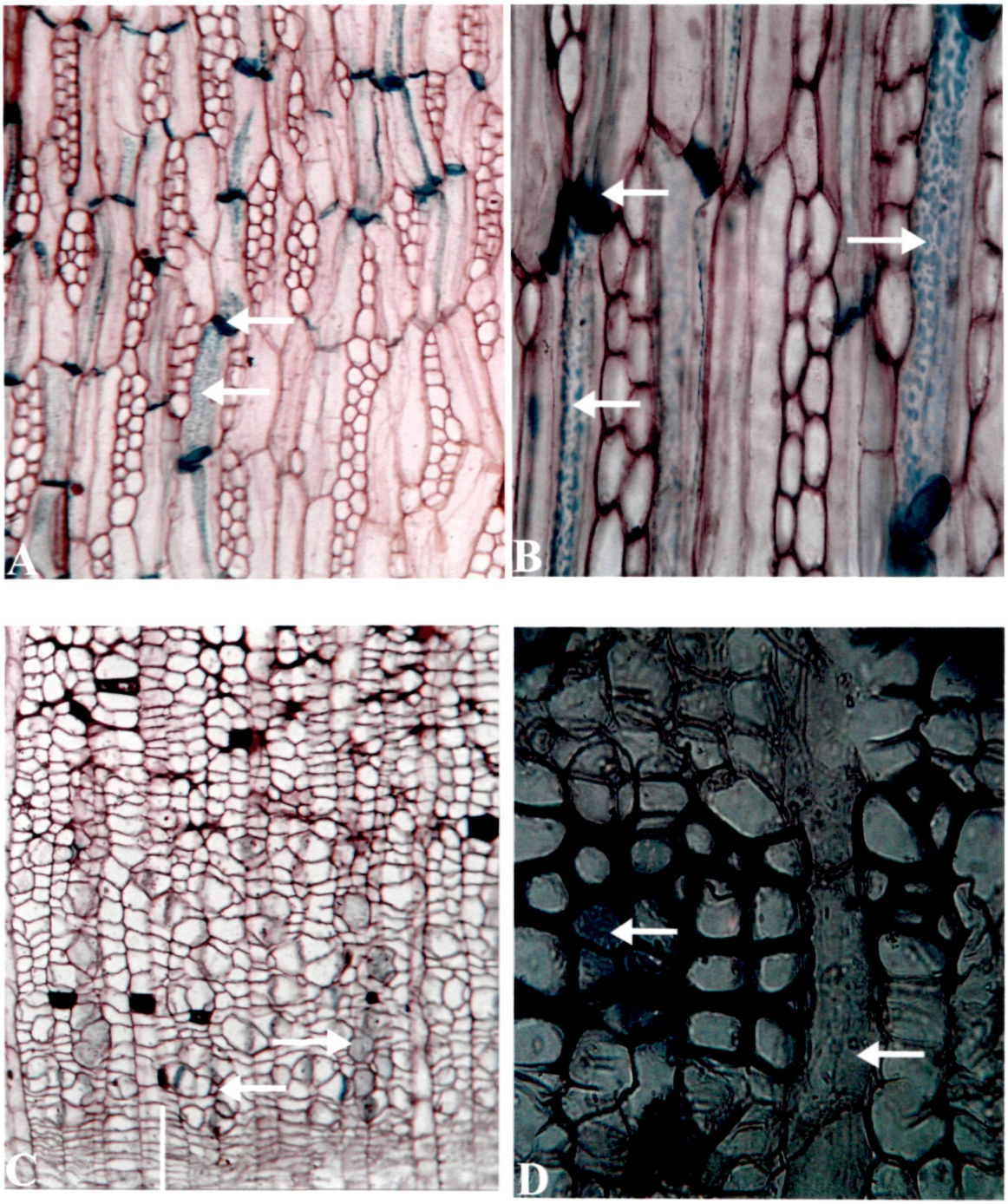

PLATE-XIV

PLATE-XV

Photomicrographs of cambial zone and vascular derivatives of *C. pentandra*

A: T.S. showing sclerenchyma (unlabelled arrow) new phloem (NP), cambium (C) and new xylem (NX) at 4X.

B: T.S. showing sclerenchyma, partly crushed sieve elements (unlabelled arrows) and new xylem (NX) at 10X.

C: T.S. showing sieve tube (unlabelled arrows) and new xylem (NX) at 10X.

D: T.S. showing sclerenchyma, completely crushed sieve elements (unlabelled arrows) at 40X.

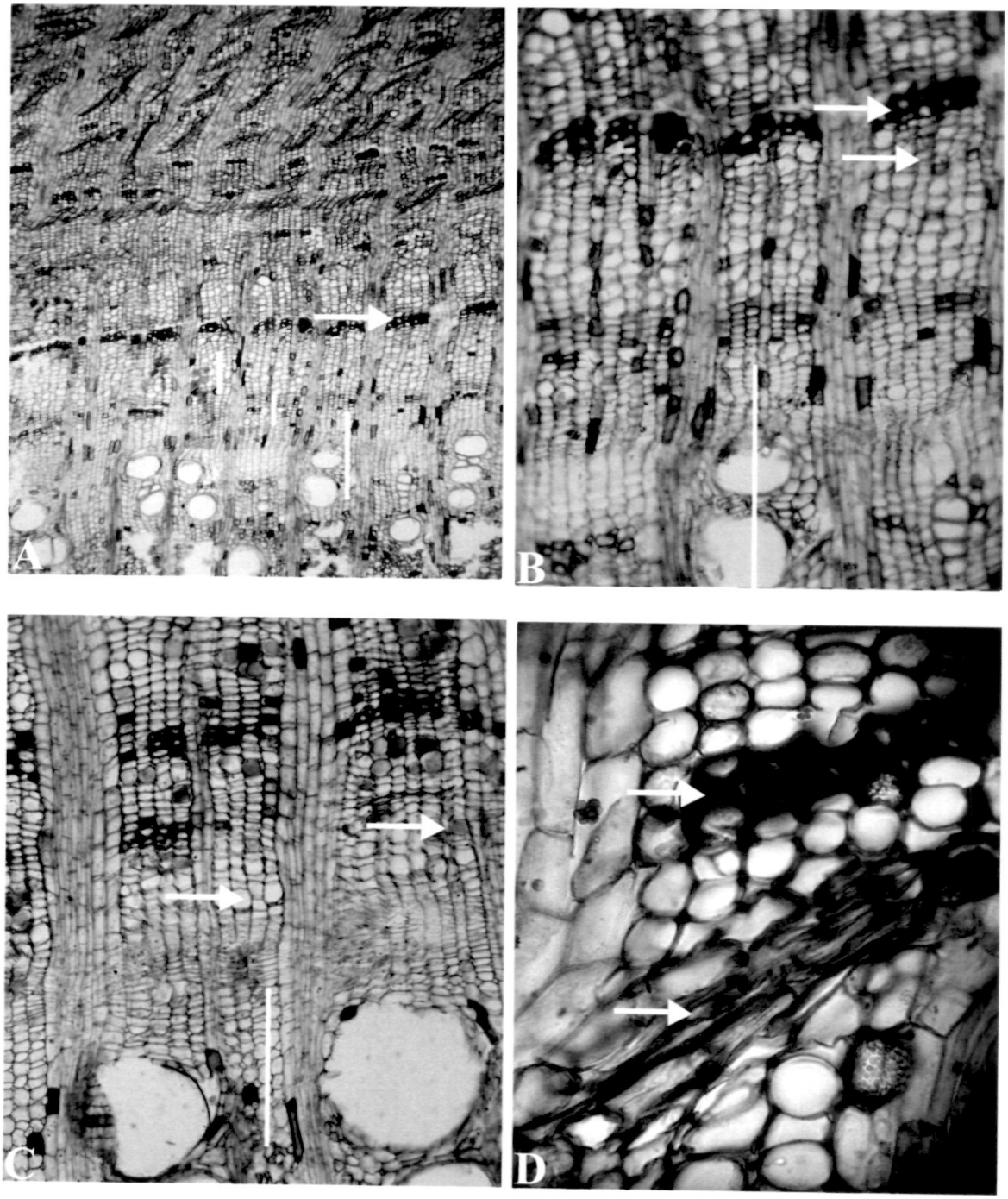

PLATE-XV

PLATE-XVI

Photomicrographs of cambial zone and vascular derivatives of *F. glomerata*

A: T.S. showing phloem rays (unlabelled arrow) and various components at 4X.

B: T.S. showing xylem fibres (unlabelled arrow), non-conducting phloem (NCP), conducting phloem (CP), cambial zone (C) and new xylem (NX) at 10X.

C: T.S. showing phloem (P), cambial zone (C) and new xylem (NX) at 10X.

D: T.S. showing phloem rays (unlabelled arrow) at 10X.

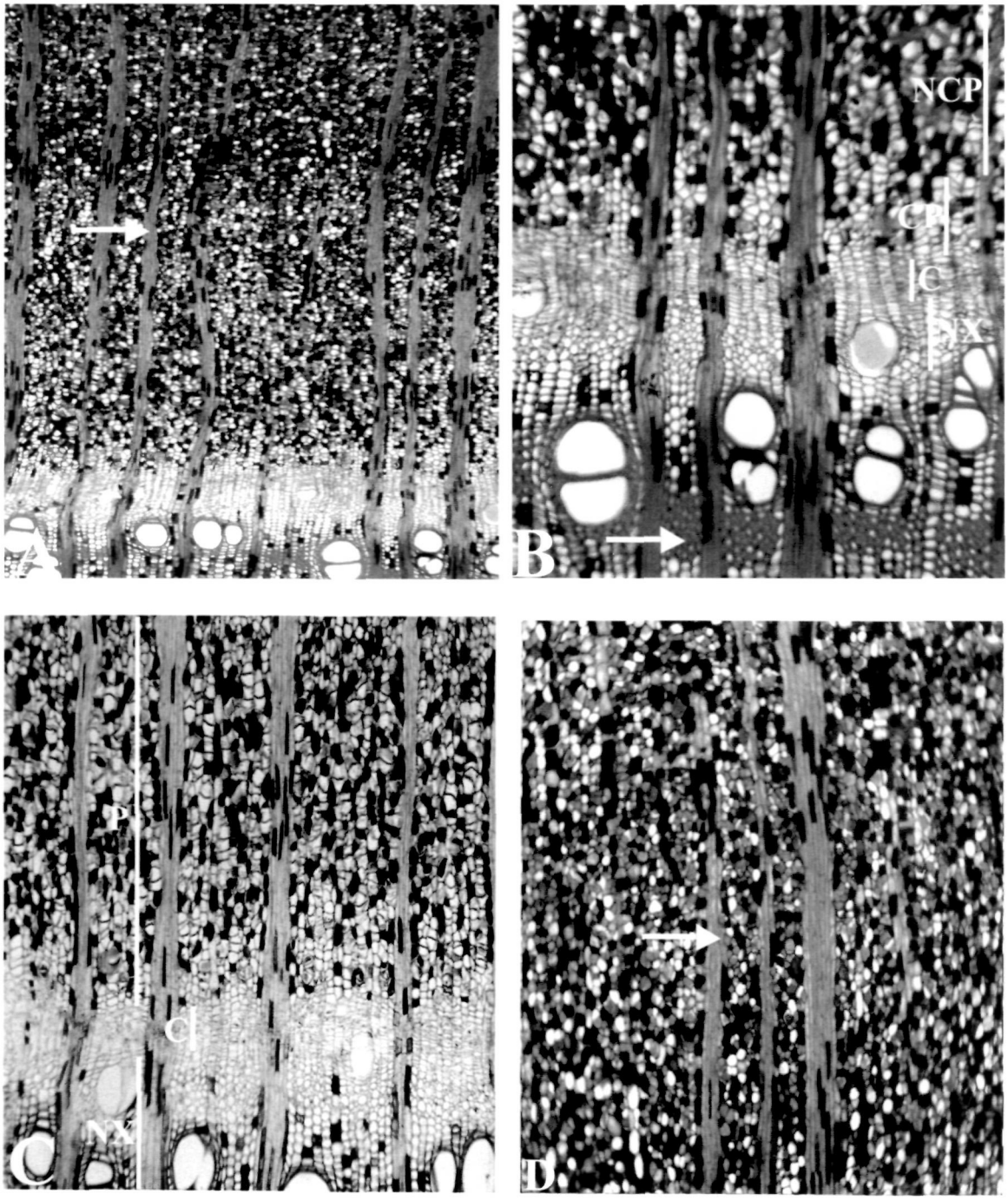

PLATE-XVI

PLATE-XVII

Photomicrographs of cambial zone and vascular derivatives of *M. oleifera*

A: T.S. showing sclerenchyma (unlabelled arrow) new phloem (NP) at 4X.

B: T.S. showing non-conducting phloem (NCP), conducting phloem (CP), cambial zone (C) and new xylem (NX) at 10X.

C: T.S. showing phloem (P) and cambium (C) at 10X.

D: T.S. showing conducting phloem (CP), cambial zone (C) and new xylem (NX) at 10X.

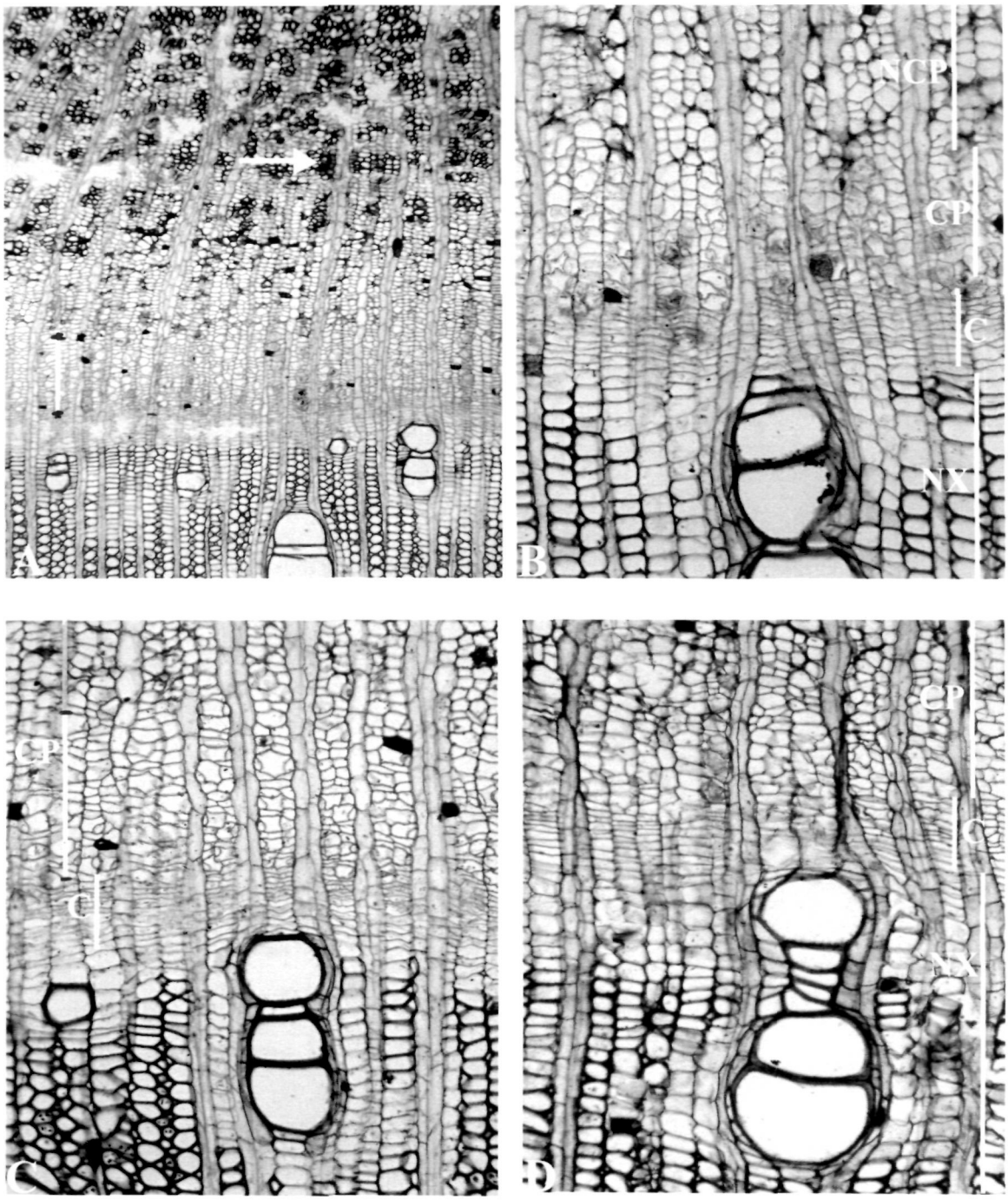

PLATE-XVII

PLATE-XVIII

Photomicrographs of cambial zone of *C. pentandra*

A: T.S. showing callose pads (unlabelled arrows) and cambial zone (C) at 40X.

B: T.S. showing cambial zone (C) at40X.

C: T.S. showing sieve tube (unlabelled arrows) and cambial zone (C) at40X.

D: T.S. showing sieve tube with companion cell (unlabelled arrows) and cambial zone (C) at40X.

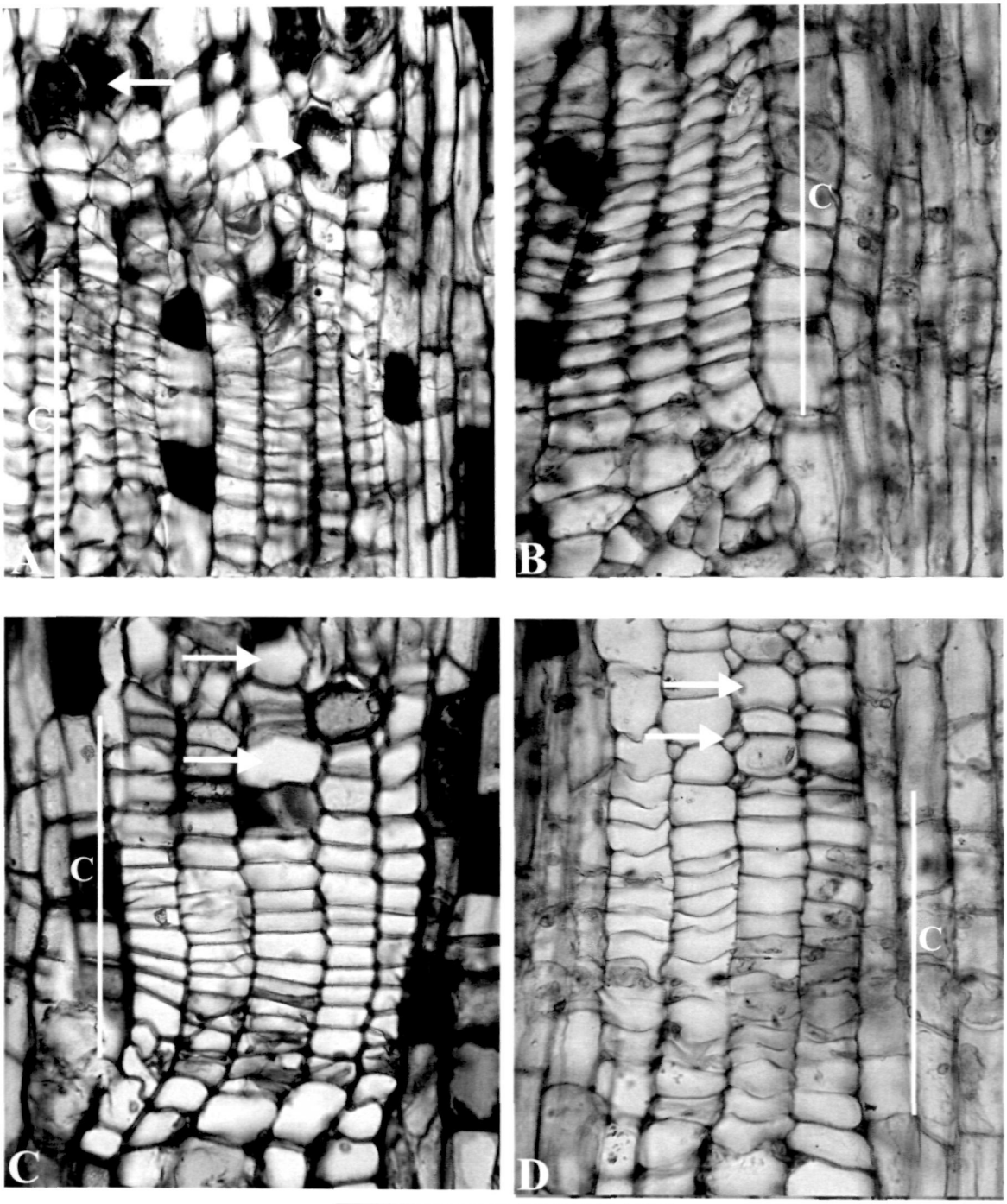

PLATE-XVIII

PLATE-XIX

Photomicrographs of cambial zone of *F. glomerata*

A: T.S. showing non-conducting phloem (NCP), conducting phloem (CP), cambial zone (C) and new xylem (NX) at10X.

B: T.S. showing new phloem (NP), cambial zone (C) and new xylem (NX) at40X.

C: T.S. showing phloem (P), cambial zone (C) and new xylem (NX) at40X.

D: T.S. showing phloem (P) and cambial zone (C) at40X.

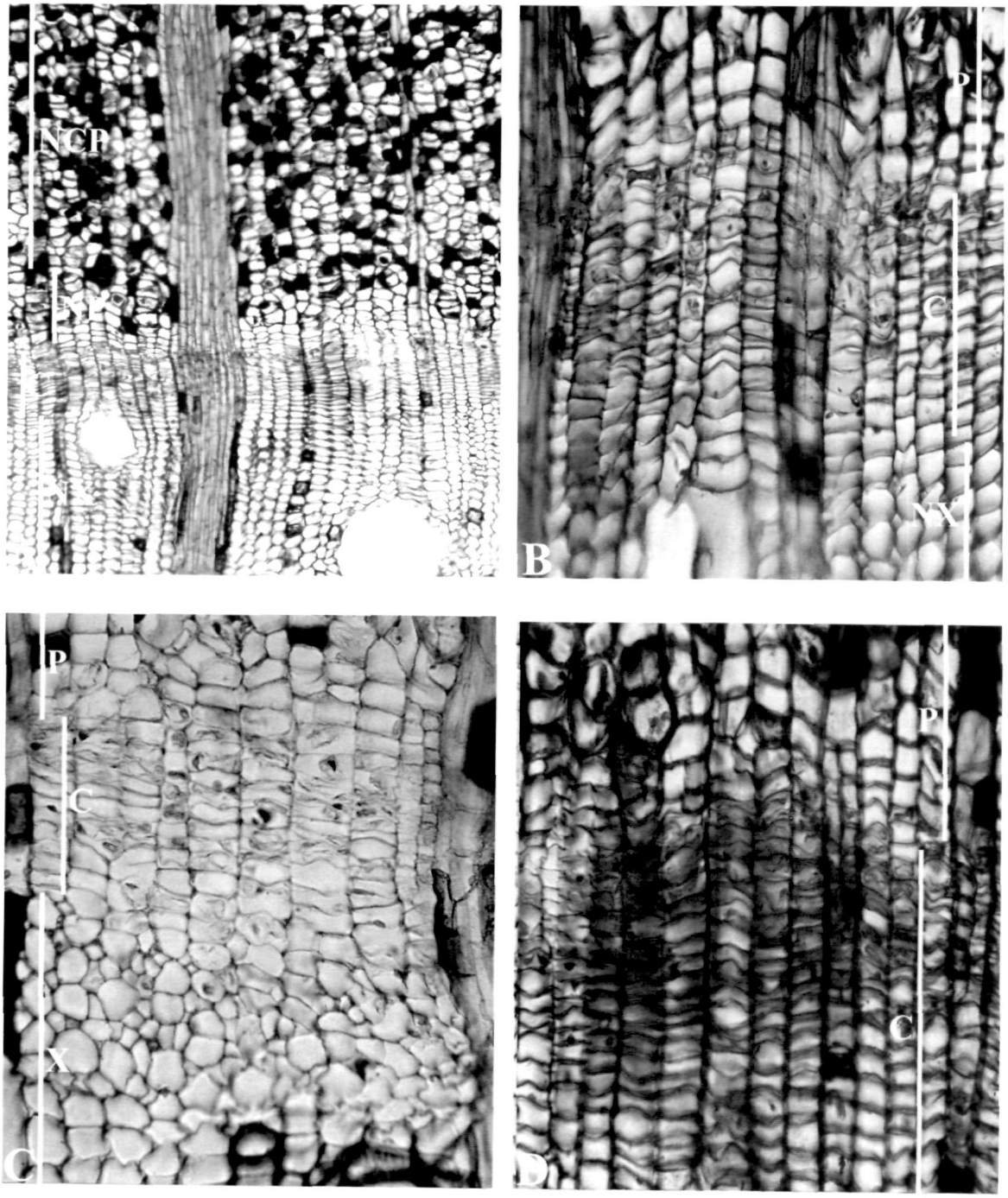

PLATE-XIX

PLATE-XX

Photomicrographs of cambial zone of *M. oleifera*

A: T.S. showing cambial zone (C) at40X.

B: T.S. showing sieve elements (unlabelled arrow), cambial zone (C) and new xylem (NX) at40X.

C: T.S. showing sieve tube with companion cell (unlabelled arrows) and cambial zone (C) at40X.

D: T.S. showing cambial zone (C) at40X.

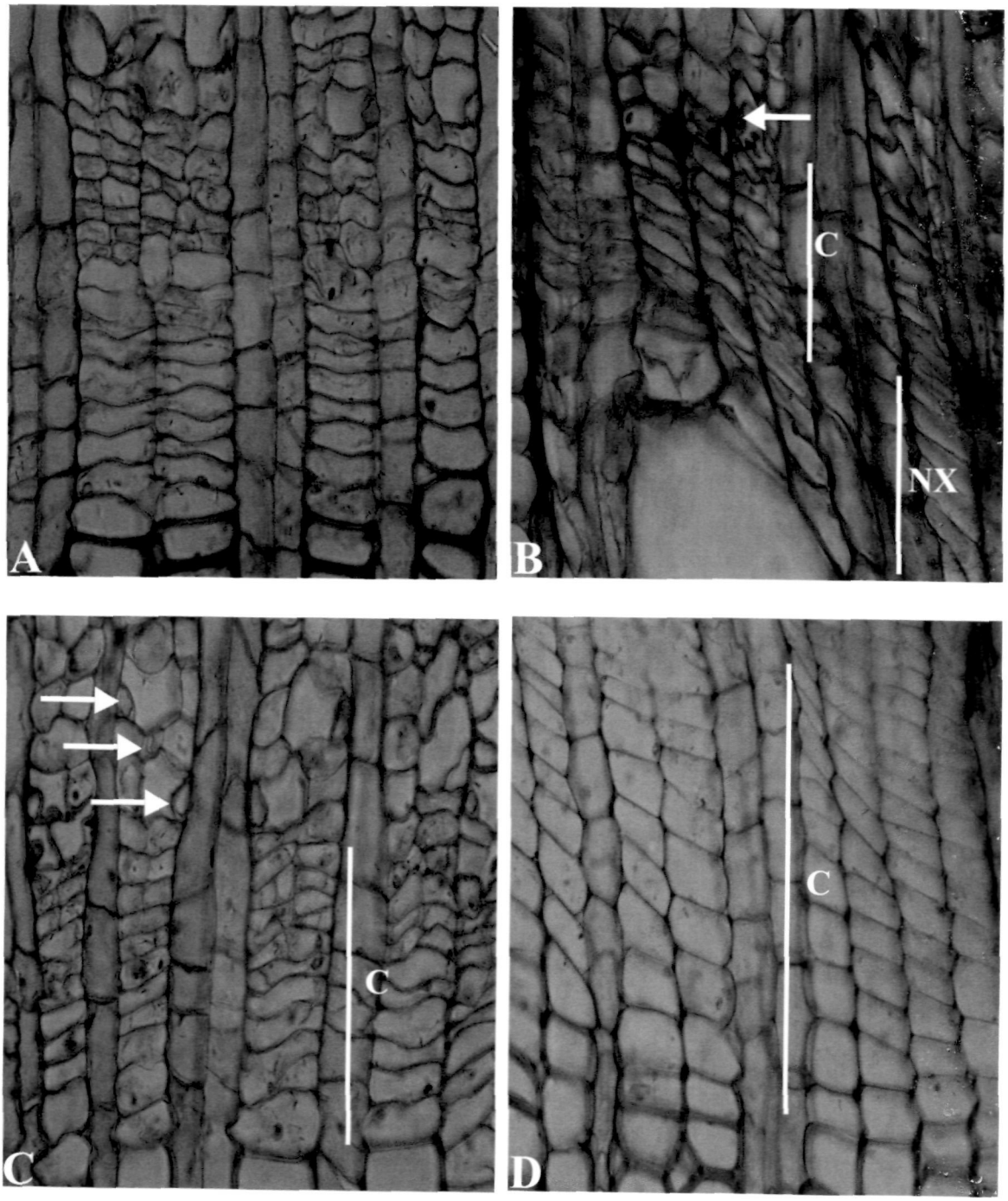

PLATE-XX